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AMPA Experimental Communications Systems

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16. Abstract

The Adaptive Multibeam Phased Array (AMPA) program was conducted to demonstrate the satellite communications advantages of Adaptive Phased Array Technology. A laboratory based experiment was designed and implemented to demonstrate a low earth orbit satellite communications system.

Using a 32 element, L-band phased array augmented with 4 sets of weights (2 for reception and 2 for transmission) a high speed digital processing system and operating against multiple user terminals and interferers, the AMPA system demonstrated:

- Communications with Austere User Terminals
- Frequency Reuse
- Communications in the Face of Interference
- Geolocation

The report describes the program and experiment objectives, defines the system hardware and software/firmware, presents the test performed and the resultant test data and draws conclusions from the test data.

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SUMMARY

The objective of this program is the development and demonstration of adaptive multibeam phased array (AMPA) technology for application to satellite communications systems. A ground based laboratory experiment was designed to simulate a low earth orbit communication system.

The AMPA hardware was fabricated and debugged; the AMPA software/firmware was written and debugged; the hardware and software/firmware were integrated and the resultant system was tested on AIL's roof antenna range.

The results of the program are:

- Higher (than earth coverage) gain, receive and transmit beams can be generated;
- They can be pointed anywhere in the field of view;
- A signal of unknown apriori location can be acquired on the basis of a distinguishing code;
- Signals can be tracked in the face of relative angular motion between the satellite and the User Terminal;
- Multiple simultaneous beams can be generated by a common set of elements without mutual interference;
- Multiple simultaneous receive and transmit beams operating on the same frequency can multiply the number of communications links that can be operated on a single frequency channel without mutual interference;
- Communications can be established and maintained in the face of interfering co-channel signals;
- The interfering signals can be much stronger than the intended communications signal and still be nulled by AMPA.
- Neither the location of the desired signal or the interferer needs to be known apriori in order for the AMPA system to provide communications in the face of co-channel interference.
- Geolocation through the technique of scanning in discrete cells was accomplished and formed the basis for the acquisition process.

The AMPA program underwent several changes of objective and scope during the development phase. Adequate funds could not be found to complete the program as planned. As a result, some problems were identified but not repaired and tests that were originally planned were not run so as to make optimum use of the available funds. Items that were affected by this limitation include:

- Noise Figure of the User Terminals
- Transmitted CNR of the User Terminals
- Variations in Element Gains, Noise Figures & ERPs.
- Transmit Null Software Demonstration

The AMPA program established the viability of both the hardware and software required for the implementation of adaptive phased array technology for satellite communications applications providing the benefits of communications service for austere terminals, enhanced use of the frequency spectrum through frequency reuse, communications in the face of co-channel interference and the by-product of coarse geolocation from a satellite platform.

1.0 Introduction

1.1 AMPA Program Objectives

The objectives of the Adaptive Multibeam Phased Array (AMPA) Communication System are to demonstrate advances in applied technology that will improve satellite communications (and communications related applications) in terms of achievable performance, cost, use of the radio spectrum and limited orbital slots.

The phased array aspect of the program allows for large low tolerance structures, distributed efficient solid state amplifiers and graceful degradation .

The multiple beams on receive and transmit allows the servicing of multiple simultaneous users with different EIRPs and G/Ts. The higher than earth coverage gain allows the user terminals to operate at lower gains and hence to be producible at substantially lower cost.

The adaptive aspect of the program permits operation in the real world of radio frequency interference, geographical flux density limitations, limited frequency allocations and an already crowded geostationary parking lot.

Demonstration of the AMPA technologies have applications both directly at the L-band experiment frequency and generally to all communication's satellite programs. Examples of applications include:

Maritime Communications - Current programs use earth coverage satellite antennas which results in expensive ship terminals which has severely limited their acceptance in the maritime community. AMPA provides the technology demonstration basis for a 2nd generation of Maritime Communications Satellites that can operate with inexpensive terminals.

Aeronautical Communications - Both political and technical reasons have delayed the application of Communications Satellites to over-water aeronautical communications. The AMPA technology eliminates some of the technical limitations and both permits communications with very austere airplane terminals and provides a ready means for surveillance of air traffic.

Spectrum Utilization - The AMPA technology has a dual impact on the use and allocation of the radio spectrum. First, the multiple simultaneous beams

provides multiple use of a single frequency channel, thus providing direct multiplication of the number of users per channel. Second, the dispersion of IM products by a phased array permits the contiguous spacing of communications channel allocations while maintaining the inherent efficiency of quasi-linear amplifiers.

<u>Communications in the Face of Interference</u> - A corollary to efficient use of the allocated spectrum is the practical application of operating in the face of co-channel interference. Intentionally or unintentionally, everyone does not play by the allocation rules. As user terminals become smaller the likelihood of interference grows. AMPA demonstrates that spatially disjoint co-channel interferers (even of substantial strength and small angular separation) can be nulled and intended communications can be implemented.

<u>Flux Density Control</u> - The AMPA technology demonstrates that shaped transmit beams, whose shape can be adapted with time, will permit simultaneous utilization of spectrum for both satellite and terrestrial applications.

<u>Data Collection</u> - The large coverage, high gain features of the AMPA technology, when combined with the computer driven acquisition and retrodirective features of the system have application to large scale readout of very austere data collection terminals.

<u>Geolocation</u> - The direction finding technology implemented in AMPA (through a variety of algorithms) will have application for a variety of search and rescue situations. Relay of GPS (Global Positioning Satellite) signals for remote processing by GPS receiver equipped satellites can be made possible through the use of AMPA technology.

In designing the AMPA program a key consideration was to maintain adequate flexibility to provide a sufficiently credible demonstration of the feasibility of adaptive multibeam phased arrays for all of the above applications.

1.2 Experiment Objective

The AMPA experiment was designed and developed to demonstrate the significant features and capabilities of phased array satellite communications systems. Specific experiment objectives are:

a) demonstration of communication modes,
b) demonstration of beam pointing modes,
c) demonstration of frequency reuse,
d) demonstration of geolocation capabilities,
e) simulation of on-orbit operation,
f) demonstration of IM dispersion,
g) demonstration of low cost user terminals

Communications Mode Demonstration

To demonstrate operation in the communications arena the experiment has four independent beams - two receive and two transmit. Various modes are implemented:

1) Simplex receive - simultaneous reception from two different user terminals.

2) Simplex transmit - simultaneous transmission to two user terminals.

3) Simplex receive/transmit - simultaneous reception from two user terminals and transmission to two user terminals at two other user locations.

4) Full duplex - duplex communication between two user terminals.

5) Bent pipe - reception of data from one user terminal and retransmission to another without demodulation.

Coupled with these modes, data in the form of BPSK or NBFM is communicated over the links. Demonstration of quality voice is also demonstrated by maintaining adequate signal-to-noise ratios in the absence of interfering signals.

Beam Pointing Demonstration

Three types of beam pointing and shaping are demonstrated. They are:

1) Open loop Static pointing - this is applicable to both receive

and transmit. Herein all beams can be independently pointed to any direction in the system field-of-view. The pointed direction can be specified by input azimuth and elevation angle relative to the array nadir or by latitude and longitude ground locations.

2) Adaptive pointing and beam shaping mode - only applicable to receive. This mode allows the system to acquire and track transmissions from user terminals and suppress interfering signals. A system design goal is to demonstrate the same high quality voice data in the presence of interferers.

3. Transmit beam pointing and nulling - this mode demonstrates the transmission of a usable EIRP toward a command specified direction while maintaining a null in another specified direction.

Demonstration of Frequency Reuse

The experiment also demonstrates operation utilizing frequency reuse. Under conditions of operation at the same frequency, interbeam isolation is to be maintained by forming a null of beam #1 in the direction of beam #2 and vice versa.

Demonstration of Geolocation Techniques

The phased array system has the capabilities of providing geolocation of user terminals. This can be used to automatically acquire and enable retrodirective operation or to permit duplex transmissions from user terminal to user terminal through the satellite without a priori knowledge of each user's location. Two techniques can be used to search and find the desired user or users. They are:

1) Scan the FOV (search the FOV in discrete cells, interpolate measured power.
2) Interfermoter (measure received phase differences of signal).

Simulation of Low Orbit Operation

The links, i.e., path loss and other expected link perturbations, are simulated to evaluate expected performance. The earth disk field-of-view of $\pm 60°$ is maintained. Tradeoffs in choice of EIRP and G/T values relative to orbit were considered to achieve simulated performance at minimum cost.

To further evaluate performance pertinent electrical characteristics of an operational system were evaluated. In particular, the antenna element was developed. This permits testing and performance analysis of a filled or thinned array configuration.

Demonstration of IM Dispersion

Associated with saturated class A operation is the production of IM products in the transmitter amplifiers. The phased array has the capability of dispersing these IMs spatially. If the class A amplifiers were replaced with class C the effectiveness of phased array spatial IM dispersion could be evaluated. However this was beyond the scope of this contract.

Demonstration of Low Cost User Terminals

As part of the original concept of a shuttle flight experiment, low cost User Terminals with low transmitted power and with simple omni antennas were to be supplied. However, when the program was changed to a ground based experiment the low cost User Terminals were deleted and additional User Terminal Simulators employing dish antenna and multifunction capabilities were added to simulate the low cost User Terminals.

2.0 AMPA Program Description & Implementation

To achieve the experimental objectives presented above, a simulated low earth orbit experiment was planned. The equipment that would simulate the equipment flown in space was given the nomenclature Experimental Model* while the ground portions were simulated User Terminals as part of Special Test Equipment (STE). The design implementation of the AMPA system followed the criteria outlined in Appendix A, Specification Adaptive Multibeam Array Experimental Communication System.

2.1 SYSTEM LINK ANALYSIS

The AMPA communication system is designed to support narrowband frequency modulated voice BPSK data at 1 to 32 kb/s with a predetection carrier-to-noise density (C/N_0) of +53 dB-Hz. The system is specified to operate with User terminals that exhibit +10 dBw minimum transmit power and ≥ -30 dB G/T.

Link calculations for the receiver (User to Experimental Model) and transmit (Experimental Model to User) modes have been calculated using the expression:

$$C/N_0 = \frac{P_T G_T G_R \, \alpha S}{K T_S M}$$

where,

P_T = transmitted power

G_T = transmit antenna gain

G_R = Experimental Model antenna gain

αS = system losses including free space, atmospheric, scan loss, polarization, and multipath losses

K = Boltsman's constant --228.6 dBW/Hz/K

T_S = system noise temperature

M = system design margin

* A thirty-two element thinned array.

The free space losses for the maximum slant range of 2494.55 km are, 164.74 and 164.18 dB for the received and transmit modes, respectively. The atmospheric losses are small ($\approx$ 0.16 dB). Scan loss is due to electronically steering the array $\pm$60 degrees and is 7 dB for the selected antenna element. A 0.5-dB polarization loss is allocated due to the axial ratios specified. Multipath losses have been estimated to be 0.5 dB for the circularly polarized antenna since reflected circularly polarized signals reverse their sense of polarization (especially at low grazing angles). Thus, the system losses are 172.9 dB for receive and 172.4 dB for transmit for the satellite to the horizon User.

For the receive link, the antenna temperature (T_a), calculated using the geometry shown in Figure 2-1 is:

$$T_a = 0.95 \times T_{earth} + 0.05 \times T_{sky}$$

$$T_a = 0.95(290) + (0.05)\ 30$$

$$T_a = 277\ K$$

T_R has been selected as 3.5 dB or 359 K which is an easily implemented design. Thus, T_S = 277 K + 359K = 636 K or 28 dB.

This represents an Experimental Model G/T_s of 22 - 28 = -6 dB
For a 32 element array where the peak element gain = 7 dBi

Solving for the resultant C/N_o we get:

$$\underbrace{C/N_o = +10\ dBW}_{\substack{P_T G_T \\ \text{User Terminal}}} - \underbrace{172.9}_{\alpha s} - \underbrace{6}_{G_r/T_s} + \underbrace{228.6}_{K} = 59.7\ dB\text{-}Hz$$

Thus, for the 53 dB-Hz requirement there is a 6.7 dB receive mode system margin.

For the transmit mode the resultant C/N_o can be calculated as:

$$C/N_o = \underbrace{30.5\ dBW}_{\substack{P_T G_T \\ \text{of beam}}} - \underbrace{172.4}_{\alpha s} - \underbrace{30}_{G_r/T_S} + \underbrace{228.6}_{K} = 56.7\ dB\text{-}Hz$$

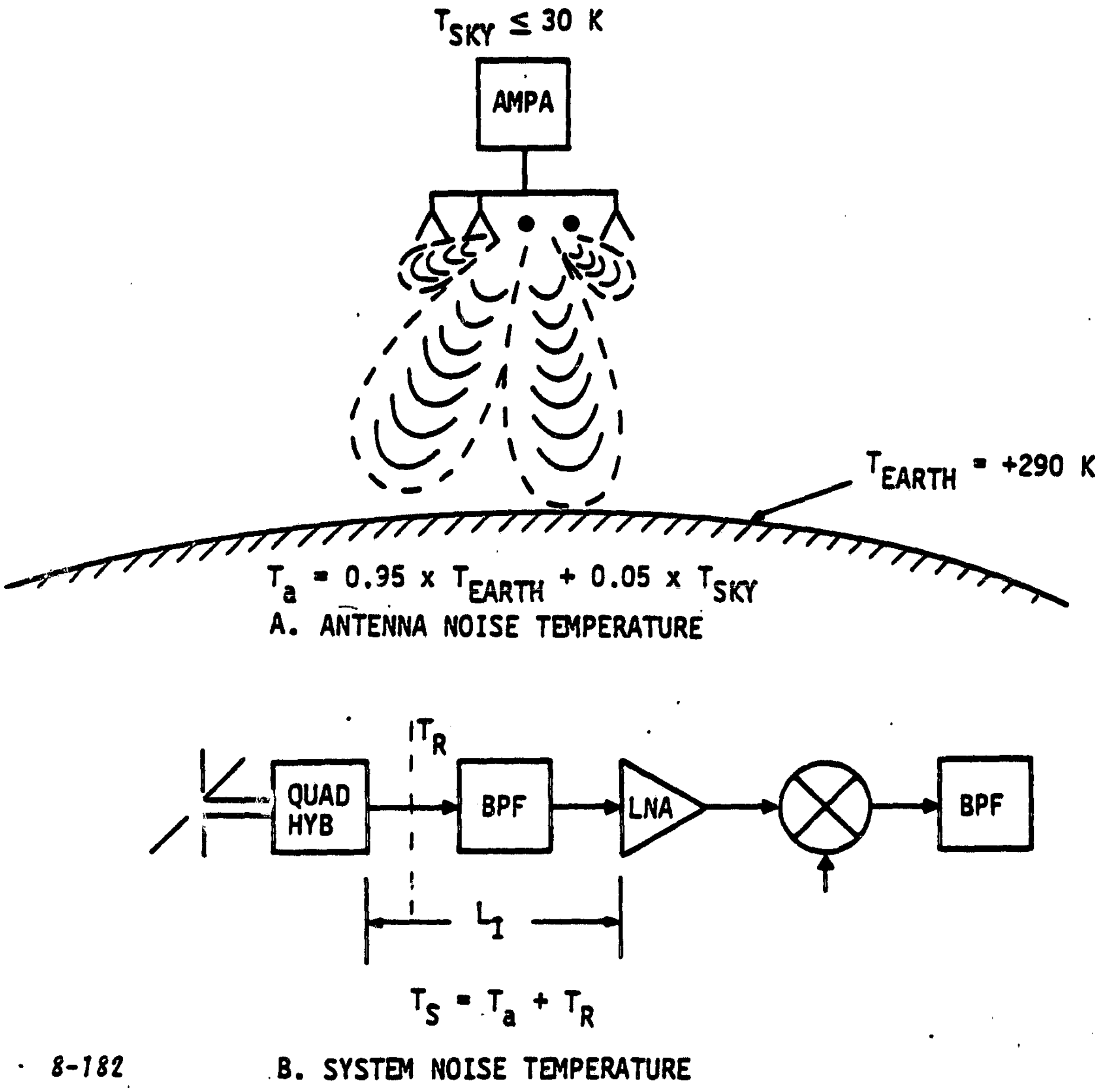

Figure 2-1. System Noise Temperature Geometry

Thus, a 3.7-dB system transmit margin exists for the selected P_TG_T for the AMPA Experimental Model. The selected P_TG_T reflects a +27.5 dBm P_{sat} for the power amplifier for two beams. This assumes a 32-element array, 22-dB array gain which is preceded by a 1-dB diplexer/cable loss.

The bent pipe or tandem link C/N_o can be characterized by:

$$Q_o = \frac{Q_1 Q_2}{Q_1 + Q_2 + 1}$$

where,

Q_o = the required output CNR at the receiving User terminal

Q_1 = the CNR required in the receive link

Q_2 = the CNR required in the transmit link

Since a horizon-to-horizon bent pipe mode is the worst case, the expected CNR for the receive and transmit modes were substituted as Q_1Q_2, respectively. This results in an output C/N_o of 50.5 dB-Hz.

The above analysis was for an operational system. The links for this program simulates the operational link.

The system losses for the antenna range for far field measurements reduces to 79.8 dB and 79.3 dB for the receive and transmit modes respectively.

The noise figure for the receiver is 17 dB or T_R = 14244°.

$$T_S = 277 + 14244 = 14521 = 41.6 \text{ dB}$$

This represents an experimental G/T_S of 22 - 41.6 = -19.6. Using the expected C/N_o of 59.7 to simulate the same margins we get

$$\underset{\text{User Terminal Simulator}}{59.7 = P_TG_T} \quad \underset{\alpha s}{- 79.8} \quad \underset{G_R/T_S}{- 19.6} \quad \underset{K}{+ 228.6}$$

or,

$$P_TG_T = -69.5 \text{ dBW}$$

For the User Terminal Simulator antenna gain 21 dB, this relates to output power of the User Terminal Simulator into the antenna of -60.5 dBm.

For the transmit mode the expected C/N_0 of 56.7 dB-Hz

$$56.7 = \underset{\substack{P_T G_T \\ \text{of beam } \alpha}}{30.5 \text{ dBW}} - \underset{\alpha s}{79.3} + \underset{\substack{\text{User Terminal} \\ \text{Simulator}}}{G/_{T_s}} + \underset{K}{228.6}$$

The $G/_{T_s}$ of the User Terminal is -123.1 dB.

For an antenna gain of 21 dB

$$T_s = 144.1 \text{ dB}$$

$$T_s = 2.5704 \times 10^{14} \text{ degrees}$$

or a 119 dB noise figure.

This is implemented by attenuators and the large loss of the cable from the antenna to the UT Simulator console.

2.2 Communication Modes

The following communications modes were to be implemented in the experimental system.

a) Simplex Receive - reception of signals from user terminal.

b) Simplex Transmit - transmission of signals from the experiment to user terminal

c) Simplex Transmit/Receive - reception of signals from user terminal and transmission to another user

d) Full Duplex - provide duplex communication link between two user terminals

e) "Bent Pipe" - reception of signals from one user terminal and retransmission, without demodulation, to another user terminal.

Independent operation of the beams in the various modes is demonstrated as well as combinations of the modes for the beam pairs. All modes accommodate BPSK or NBFM data transmissions. In all modes, the demodulated data from the receive beams is available as a hardwire output from the experimental model. The data inputs for the simplex transmit mode are hardwire inputs from the STE or other test equipment.

2.3 Beam Pointing Modes

Three beam pointing modes are provided.

a) Open Loop Pointing - this mode, which is applicable to both the transmit and receive beams, permits all beams to be pointed to any location within the field of view.

b) Adaptive pointing and beam shaping - this mode permits either or both of the receive beams to acquire and track user signals in the presence of higher power co-channel interferers.

c) Transmit beam pointing and nulling - this mode permits either or both of the transmit beams to be pointed to specified points while maintaining a null in another direction. Pointing information may be externally specified or derived from receive beam information.

All of the beams are independently configured to any of the beam pointing modes.

2.4 Receiver Modes

The AMPA adaptive receive modes can be emulated by the following simplified functional block diagram of a Maximum Signal to Interference Ratio (MSIR) Adaptive Array (Figure 2-2).

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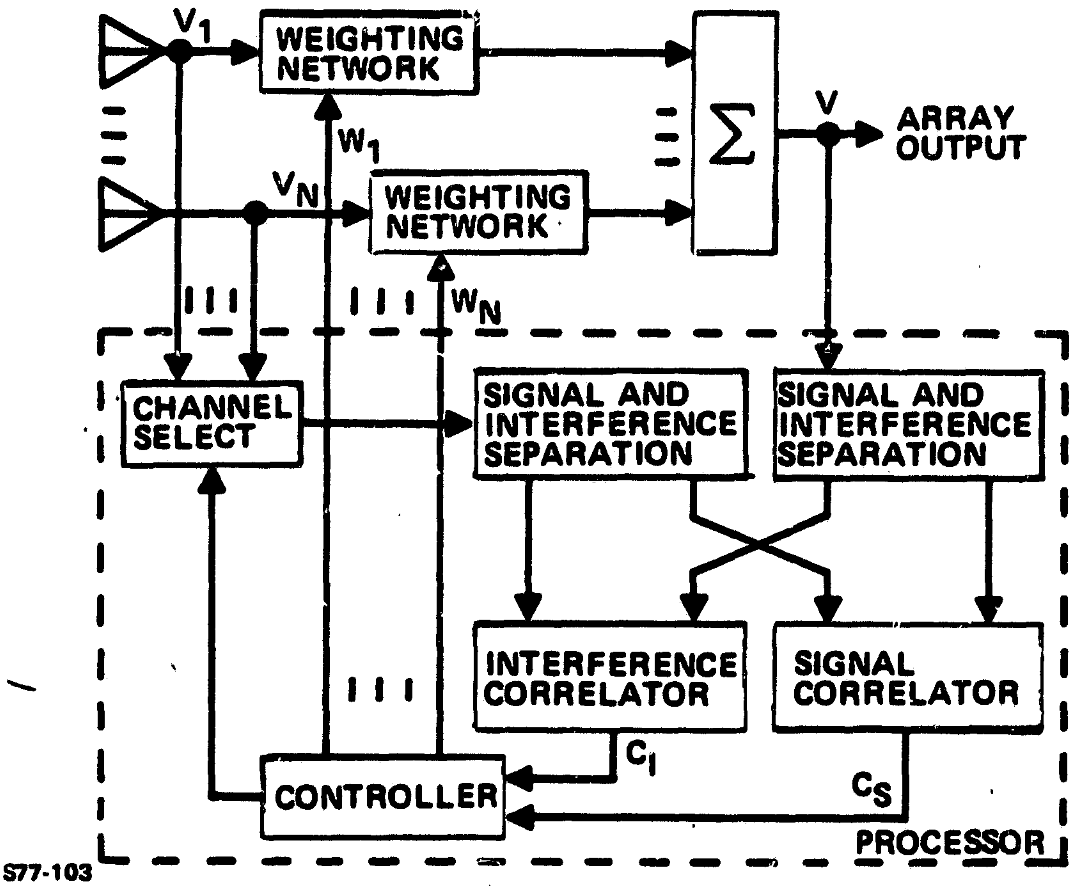


Figure 2-2 Functional Block Diagram of MSIR Adaptive Array

The array output is the sum of each weight times the element signal

$$\text{Output} = \sum_{J=1}^{N} W_J V_J(t)$$

mathematically it can be proven that the optimal weights

$$W_{opt} = u\, M^{-1} S^*$$

where

u is a scalar

M^{-1} is the inverse covariance matrix of the correlation between the elements

and

S^* is the cross correlation of the element and the sum output of the desired signal

To find the maximum weights mathematically, one takes the derivative of the output with respect to the weights and sets this gradient equal to zero. We then solve for the weights.

This is implemented in hardware and software by (refer to Figure 2-2). separating the element and sum outputs into desired signal and interference components and measuring the interference and signal correlations between the separated sum element components respectively. The gradient is then calculated by the following:

$$\text{Gradient} = \frac{C_{SK}}{P_s} - \frac{C_{IK}}{P_I} \qquad K=1,2,\ldots N$$

where

C_{SK} = cross correlation of the sum signal component with each element signal component

C_{IK} = cross correlation of the sum interference component with each element signal component

P_s = measure of sum signal component power

P_I = measure of sum interference power

This gradient is then multiplied by the preceding gradient to form the dot product. The output dot product is used to look up a step size modulator. This is an emperical number based on previous experience for convergence algorithms. The present gradient is then multiplied by the modulator to find a new step size. This step size is then added to the preceding weight to form a new weight. This process is then iteratively repeated to reduce the gradient to zero.

2.5 TEST RANGE

A far field experimental antenna test range (see Figure 2-3) was implemented on the roof of the AIL Melville facility. The 32 element array with its associated electronics was mounted on a pedestal which could rotate (for the purpose of generating antenna patterns) over the field of view. Six dish antennas (4 User Terminal Simulators and 2 interference sources) were placed over the field of view to excite the array at a distance which simulates far field conditions ($\frac{2d^2}{\lambda}$). A field probe which was used to run axial ratio measurements was also employed.

The array could be rotated 90° in elevation and 180° in azimuth to permit antenna patterns in azimuth and elevation. Eccosorb fences were used to reduce reflections and multipath.

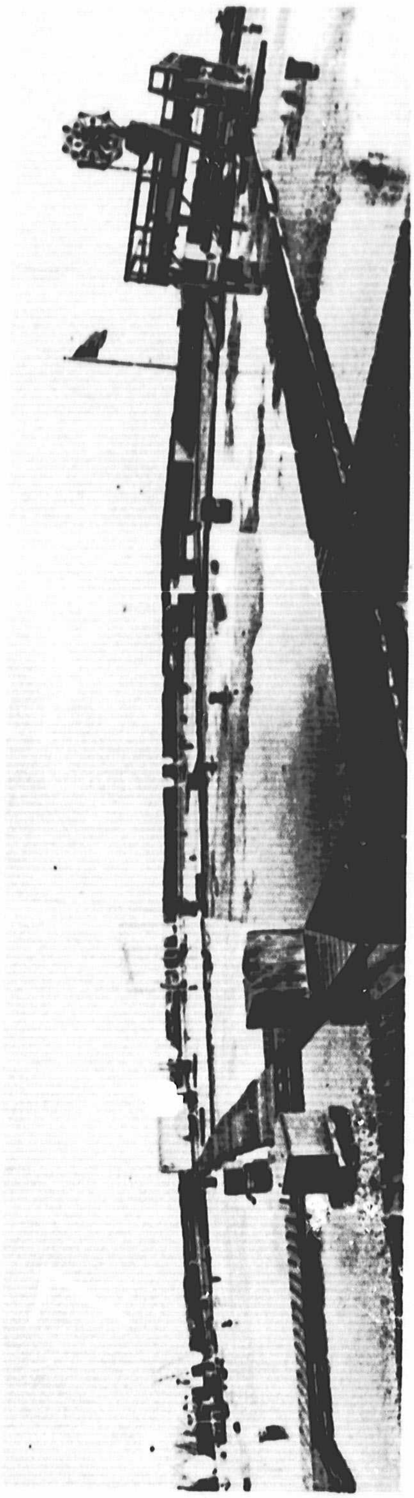


Figure 2-3 Far Field Experimental Antenna Test Range

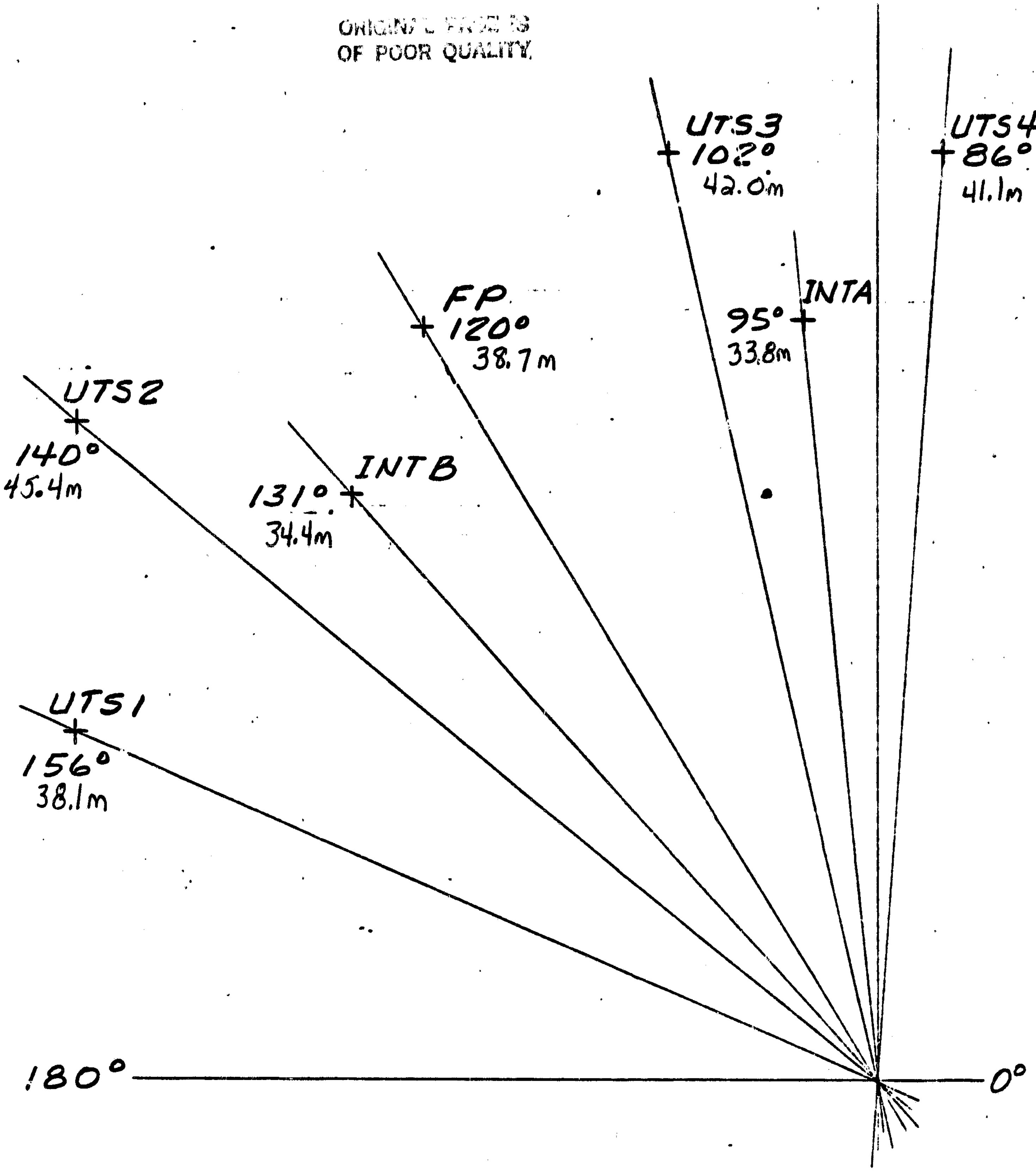


Figure 2-3a Far Field Experimental Antenna Test Range

2.6 Acquisition, Geolocation & Tracking Operation

The low earth orbit combined with the AMPA requirements to enhance desired signals while nulling interference leads to the need to search simultaneously and rapidly the space, time and frequency domains. The low earth orbit contributes both a significant maximum doppler shift and an increased maximum interference level because of the large range differential from horizon to nadir.

In the adaptive receive mode the only a'priori user parameters are the unique address code, data rate and frequency. Other parameters such as code phase, location or received power levels are not available. In addition, a relative doppler shift uncertainty exists. Acquisition must occur in an interference as well as a clear environment. In order to overcome a large interferer, some processing gain must be obtained by means of spatial discrimination, code waveform, or in long integration times to enhance desired code reception.

An initial arbitrary criterion has been set, i.e., acquisition will be said to occur when the user code to noise ratio exceeds 13.4 dB. This corresponds to a 95% probability of detection with a false alarm rate of 10^{-4}. Other less stringent false alarm rates could be tolerated. However, to initially evaluate the system this threshold was selected.

The acquisition process can be described by the following flow diagram (see Figure 2-4). The field-of-view is divided into 248 overlapping cells each corresponding to the HPBW of the beam for a 16 element array. The use of 32 elements would increase the number of cells by four (4), thus increasing the acquisition time by four (4). Each cell center will have a distinct doppler frequency that corresponds to that angle with respect to the spacecraft's motion. Thus, a coarse doppler correction can be calculated for each cell. The coarse doppler then would have a maximum uncertainty of ± 4 kHz (corresponding to farthest cell and the path of the spacecraft). The criteria for acquisition is then set as passing the desired code to noise threshold of 13.4 dB and locking the signal to ± 4 kHz of the coarse doppler frequency.

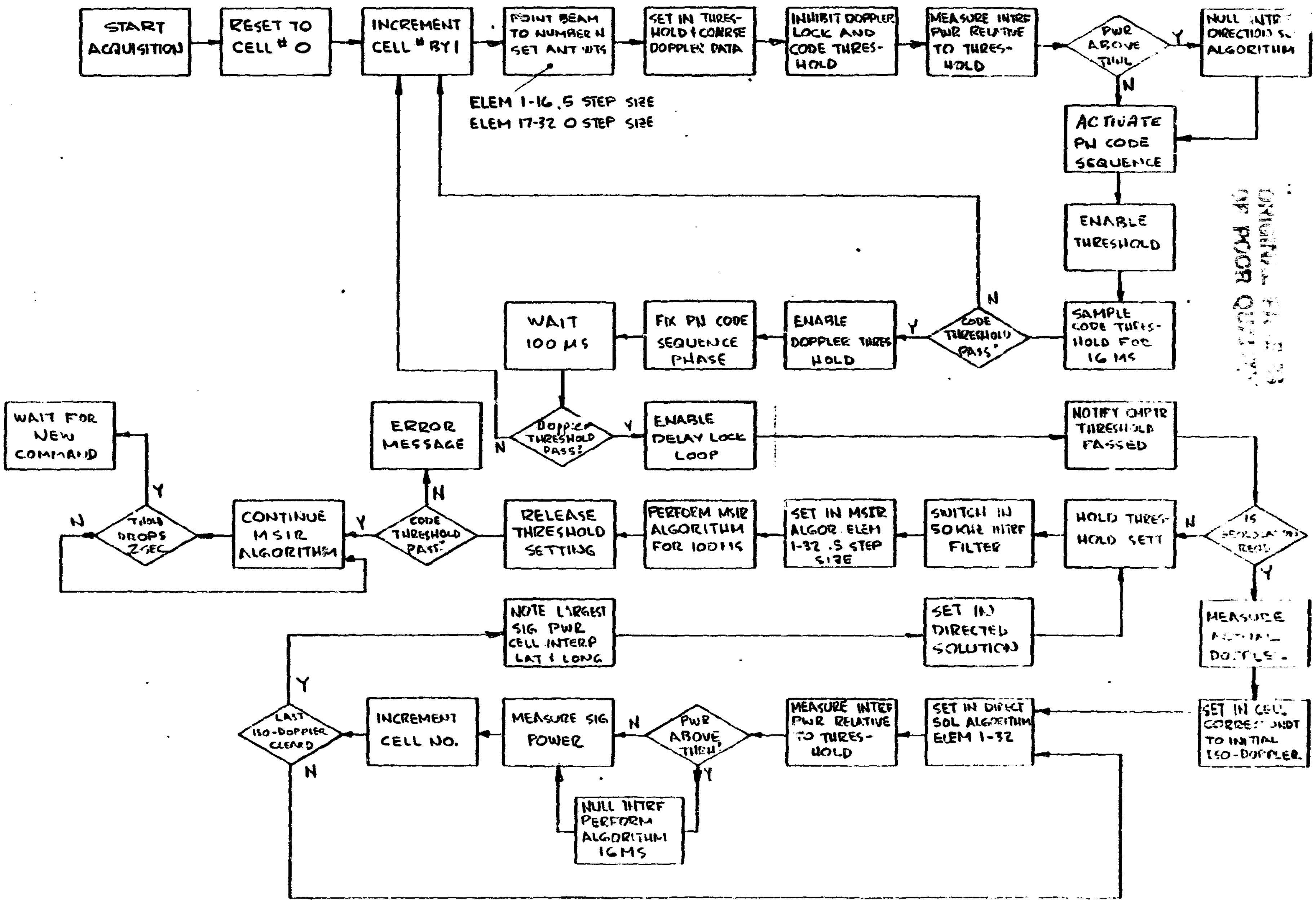
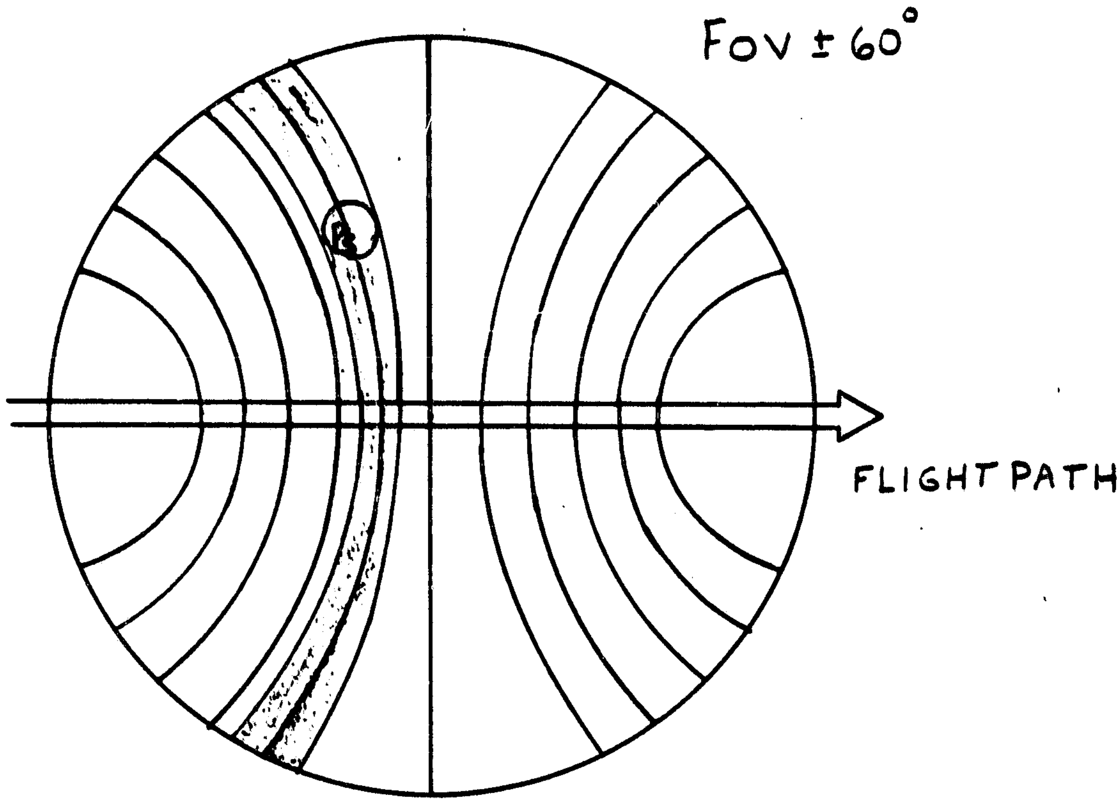


Figure 2-4 Acquisition Flow Diagram

Cell number one (1) is selected. The Host computer calculates the weights to point the array to cell number one (1). It also calculates the coarse doppler and a threshold setting which corresponds to this cell. A threshold setting is required to present a false lock to an undesired user at or near nadir when looking at his cell. This is required because there is only 11 dB orthogonality between codes and a 15 dB dynamic range from horizon to nadir could overcome the orthogonality. The weights (doppler and threshold) are sent from the Host Processor to the DEP. The DEP transfers the weights to the Weighting Networks in the Receiver Processor and sends the doppler correction and threshold to the Signal Processor. The DEP also sends a code inhibit to the Signal Processor. This prevents the code generator in the Signal Processor from phase matching to the received code. The interference sum power from the Signal Processor is then measured in the DEP and compared to a noise level threshold. If the interference power is above noise this will indicate an interference environment. The interferer must first be nulled so the phase matching of the code can be accomplished. This is accomplished by the use of the Directed Solution Algorithm which nulls the interferer within 20 iterations. After nulling or if a clear environment was detected the code inhibit is negated and the received user signal is compared to the internal generated code utilizing a sliding correlator technique which is discussed in Section 3.1.2. The maximum time for all possible combinations of code phasing to occur and achieve threshold is 16 MS. If code lock is not achieved within this time the DEP will then tell the Host Processor to direct it to the next cell and the process repeats itself. However, if code lock does occur, the received signal is checked for "in band" integrity and if in band will lock up to the doppler oscillator in the Signal Processor. When this occurs the Signal Processor notifies the DEP which in turn notifies the Host Processor that acquisition has occurred. A data word is sent to the Host from the DEP giving weight states, measured doppler, signal and interference power. If no geolocation is required the Host will send a track word to the DEP to begin track operation. The track word consists of the weights (now 32 elements) to point the beam to the center of the acquired cell. The acquisition process is repeated as if it never occurred for this cell. If no new code and doppler lock occur then the previous acquisition was in error and an error message is generated. If new

acquisition occurs then the DEP will reset the threshold setting to the Signal Processor. It will also switch from the Directed Solution Algorithm to the MSIR algorithm. Operation will continue until the Signal Processor loses doppler and/or code lock for two (2) consecutive seconds. When this occurs an error message will be generated.

If geolocation was required an iso doppler contour of the FOV (Figure 2-5) is calculated which corresponds to the measured doppler. This iso doppler contour is divided into cells corresponding to a 32 element array. Each cell is searched similar to the acquisition mode until all cells have been searched. The measured signal power is then used to determine the geolocation of the received user. The coordinates of this location are then used to form the weights for the track mode which is called as described above.



Iso-Doppler Contour Lines

Figure 2-5

3.0 AMPA Experimental Communications System Hardware Design

The AMPA system hardware consists of a laboratory Experimental Model and Special Test Equipment (STE) which includes User Terminal Simulators.

The AMPA Experimental Model is the simulated segment of an advanced communications system which would be flown on an earth-viewing polar orbit low-altitude satellite.

The philosophy guiding the hardware design was to provide an advanced technology base for future operational satellite communications relay platforms. The Experimental Model utilizes phased array techniques to enhance communication performance in an interference environment, increases overall capacity with multiple simultaneous links, improves spectral utilization through frequency reuse by way of spatial filtering and most significantly, minimizes the cost of User Terminals. The experiment also provides additional technology advancements such as acquisition and tracking under high satellite flight dynamics, large doppler uncertainty and large angular coverage with the presence of grating lobes in the field-of-view (FOV).

The Special Test Equipment and test range facilities provide the capabilities to evaluate all aspects of the Experimental Model operation including RF and communications subsystem performance in all modes. The STE design and implementation, include a central computer (PDP 11/34) with means for mapping and recording array data, an RF Scenario and a Manual Test Rack. The RF scenario includes four (4) simulated User Terminals and two (2) Interference Sources. The Manual Test Rack provides a means for preliminary testing of the array without the use of the computer. It is also used as the source for DC power for the array during experimental operations.

The design specifications and characteristics of the hardware are described in this section.

3.1 Experimental Model - Figure 3-1

The Experimental Model is subdivided into two (2) subsystems, i.e., the Array Subsystem and the Module Subsystem. The array subsystem consists of the antenna array and the receiver and transmitter components that are integral to the performance of the subystem. The local oscillator for the array is derived from a reference which is supplied by the module subsystem. The array subsystem simulates the satellite equipment for an AGIPA (Adaptive Ground Implemented Phased Array) low or geosynchronous operational system.

The module subsystem consists of the processing equipment for the array, i.e., the Receiver Processor which contains the receive weighting networks, the Transmitter Processor which contains the transmit weighting networks and the frequency references for the local oscillator, the Signal Processor which contains the code and doppler acquisition circuitry and the Modem which provides the data demodulation and modulation. Also included is the (DEP) Dedicated Experiment Processor where the required high speed execution of the adaptive algorithms and the interface for the computer is provided.

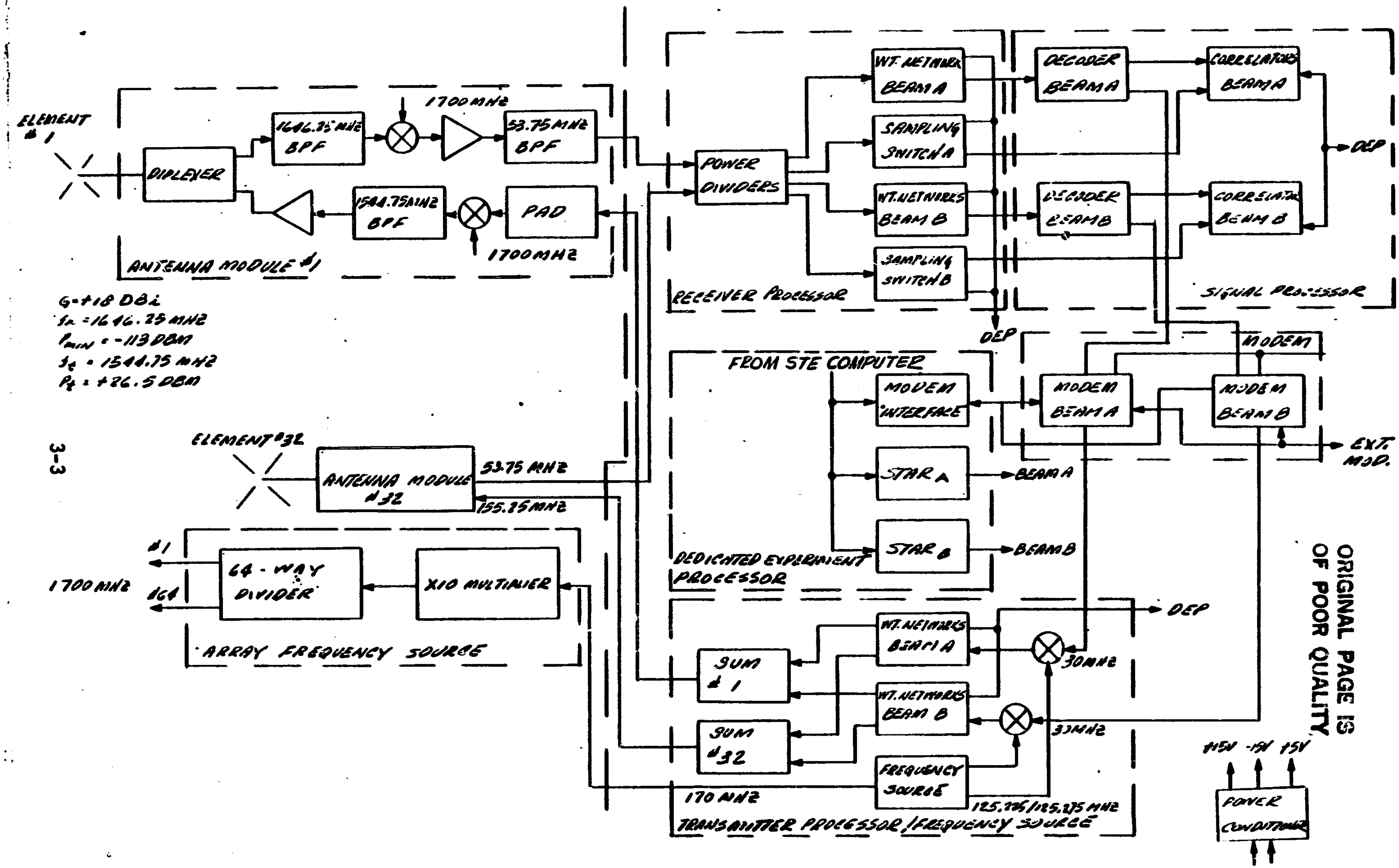


FIGURE 3-1 AMPA EXPERIMENTAL MODEL BLOCK DIAGRAM

3.1.1 Array Subsystem

The array subsystem is shown in

Figure 3-2

Requirements

The Array Subsystem consists of a 32 element array, 32 antenna modules (Diplexer, Transmitter & Receiver) and a multiplier unit with power dividers which provide the LO distribution. The Array Subsystem has the following characteristics:

Receive Frequency:	1646.25 MHz nominal
Transmit Frequency:	1544.75 MHz nominal
Polarization:	LHCP (Receive & Transmit)
Array Beamwidth:	5° on Boresite
Array Gain:	22 DBIC min.
Side Lobes:	10 dB below the peak of main beam
Receiver Gain:	13 dB min.
Receiver Noise Figure:	17 dB max.
Receiver Bandwidth:	2.5 MHz nominal
Image Rejection:	120 dB min.
EIRP:	+30.5 dBW

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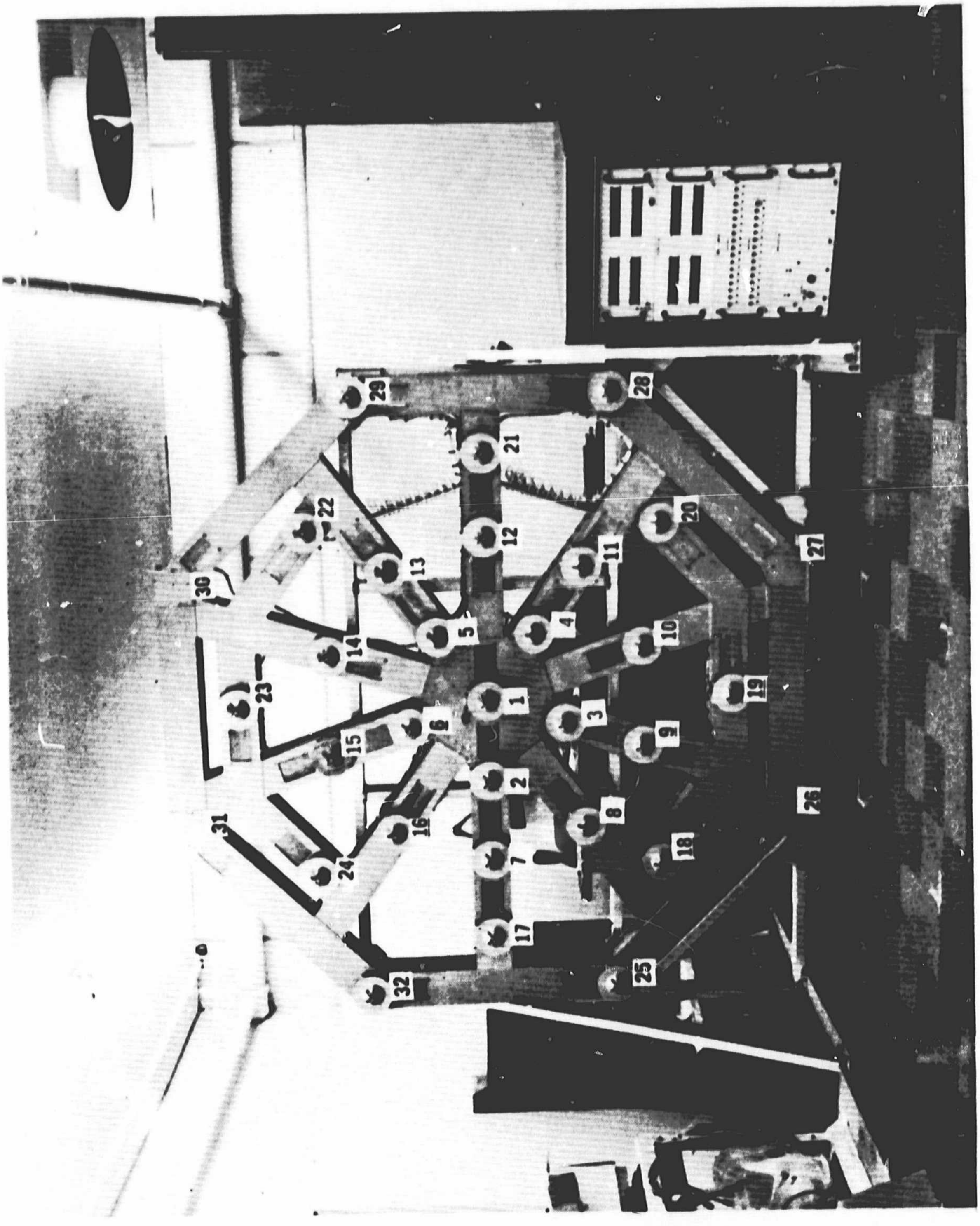

Figure 3-2 The Array Subsystem

Each antenna element provides LHCP for simultaneous transmit and receive. The element spacing & configuration was chosen to minimize grating lobes over the FOV. The antenna elements connect to the diplexer subassembly of the antenna modules. The diplexer provides the isolation between receive and transmit frequencies. The receiver section of the antenna module downconverts the received signal to nominally 53.75 MHz by mixing with a 1700 MHz LO. The transmitter section of the antenna module upconverts the input signal to nominally 1544.75 MHz by mixing with a 1700 MHz LO.

A X10 multiplier unit multiplies and amplifies the input 170 MHz signal to 1700 MHz. The 1700 MHz is then fed to a 64-way divider which consists of nine 8-way power dividers. The resulting 64 outputs are used as LO's for the antenna modules. Semirigid coaxial cable is used for all LO connections. The assembly is mounted to a rigid antenna array structure which was designed to operate in a space environment (original requirement). However, the thermal blanketing which would have controlled the component temperature environment has been eliminated. The array structure was designed to meet requirements for Shuttle/Spacelab integration although no qualification testing was done.

3.1.1.1 Antenna Array Structure (563453) Figure 3-3

The Antenna Array Structure is a lightweight stiff sheet metal support and base for 32 antenna modules. Modules are positioned on equally concentric circles of 11.5 inch radial increments around a center module. Typical cross section of the structure is a box beam approximately 4 inches by 6 inches of formed .032 inch thick 6061T6 aluminum alloy. The top surface of the structure in effect is a ground plane on which the antenna elements are mounted to the permanently riveted covers. The underside of the structure has a combination of permanently mounted covers and dismountable covers for access to the antenna

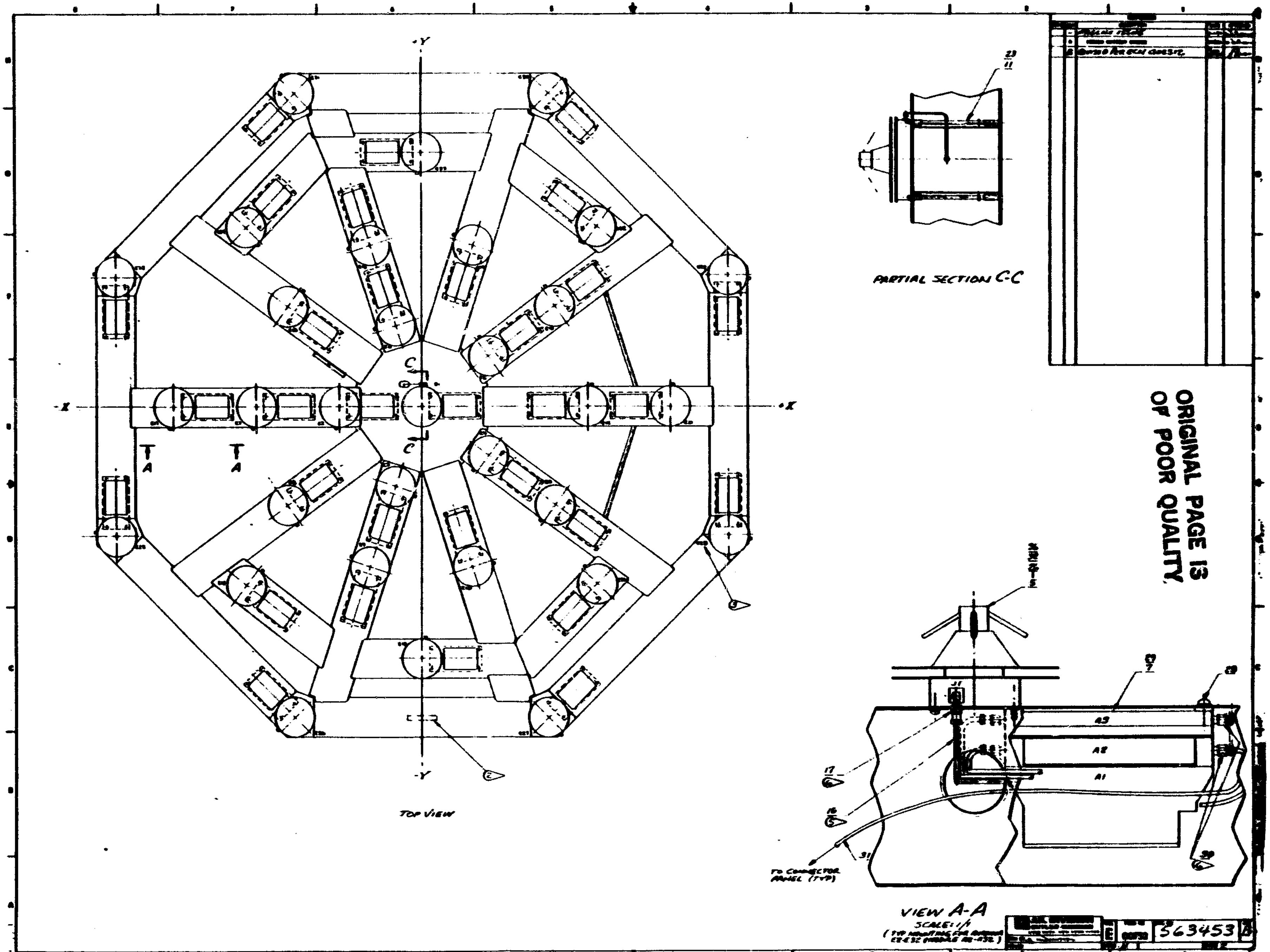

Figure 3-3 Antenna Array Structure Drawing No. 563453

modules. Interconnections between antenna elements, antenna modules, power dividers and the multiplier are made with semirigid coax cabling. There are eight 5/16 inch diameter mounting holes at each intersection of the sides of the octagon to interface with GE Structure #47D252766. The power dividers, multiplier and DC power connector are mounted on the underside of the array structure.

3.1.1.2 Antenna Element

The antenna element is used to provide sufficient gain over the field-of-view. The element is used simultaneously for both receive and transmit functions.

Element Type:	Dipole - Slot
Gain (Boresite):	7 DBI
$\pm 40°$ from Boresite:	3 DBI
$\pm 60°$ from Boresite:	0 DBI
Frequency:	1540 MHz to 1645 MHz
Polarization:	LHCP
VSWR:	1.3:1
Ellipticity:	3.0 dB within $\pm 60°$ of boresite over the frequency range

The element assembly contains a quadrature hybrid which provides the phase quadrature feed for the dipoles thus producing the orthogonality required for circular polarization. A single SMA connector is provided which interfaces with the diplexer portion of the antenna module.

3.1.1.3 Antenna Module

The Antenna Module consists of a diplexer, receiver and transmitter. It provides amplification in the receive mode and sufficient output power in the transmit mode to satisfy the Experimental Model requirements. The Antenna Module provides the respective conversions to and from IF to interface with the module subsystem. The Antenna Module characteristics are as follows:

Input Receiver Frequency:	1646.25 MHz nominal
Output Receiver Frequency:	53.75 MHz nominal
Input Transmitter Frequency:	155.25 MHz nominal
Output Transmitter Frequency:	1544.75 MHz nominal
Receiver Gain:	13 dB min.
Receiver Noise Figure:	17 dB max.
Receiver Bandwidth:	2.5 MHz nominal
Image Rejection:	120 dB min.
Transmitter Frequency Rejection:	120 dB min.
Transmitter Output Power:	+26.5 dBm min.

The Diplexer separates the receive and transmit frequencies and provides the common interface to the antenna element. The receiver consists of a bandpass filter and mixer followed by an amplifier and IF bandpass filter. The input 1646.25 MHz signal is downconverted to 53.75 MHz by mixing with a 1700 MHz LO.

The transmitter portion of the Antenna Module accepts the 155.25 MHz signal and upconverts it to 1544.75 MHz with the aid of a 1700 MHz LO. A class A biased power amplifier is utilized providing the required output power.

The Antenna Module consists of the diplexer, receiver and transmitter modules bolted together.

3.1.1.4 Diplexer

The Diplexer provides the common interface to the antenna element for the receiver and transmitter modules. The Diplexer also provides the isolation between receiver and transmitter frequencies. The Diplexer characteristics are as follows:

Receiver Frequency:	1646.25 MHz nominal
Transmitter Frequency:	1544.75 MHz nominal
Insertion Loss (both frequencies)	1.0 dB max.
Receiver Filter Rejection:	@1753.25 MHz 70 dB min.
	@1544.75 MHz 70 dB min.
	@1700 MHz 40 dB min.
Transmitter Filter Rejection:	@1646.25 MHz 70 dB min.
	@1700 MHz 70 dB min.
Bandwidth:	15 MHz nominal
VSWR (all ports).	1.5:1 max.

The Diplexer consists of 3-pole coaxial resonator type filters for both the receiver and transmitter signal paths. The transmitter filter section of the Diplexer rejects the transmitter output noise by 70 dB at the receiver frequency (1646.25 MHz). The insertion loss is less than 1.0 dB so as to limit the transmitter amplifier output power requirements.

The receiver filter section of the Diplexer provides 70 dB rejection to the transmitter signal so as to limit spurious responses at the receiver module.

3.1.1.5 Receiver Module

Schematic - 562861 Figure 3-4

The Receiver provides the downconversion from RF to IF. In addition to providing gain it contains RF filtering to reduce the spurious responses caused by transmitter leakage and image frequencies. The Receiver characteristics are as follows:

Input Frequency:	1646.25 MHz nominal
Output Frequency:	53.75 MHz nominal
IF Bandwidth:	2.5 MHz nominal
Noise Figure:	16 dB max.
Gain:	14 dB min.

REV – 562861

ZONE	LTR	DESCRIPTION	DATE	APPROVAL
	–	PRELIM ISSUE	12-5-79	[illegible]

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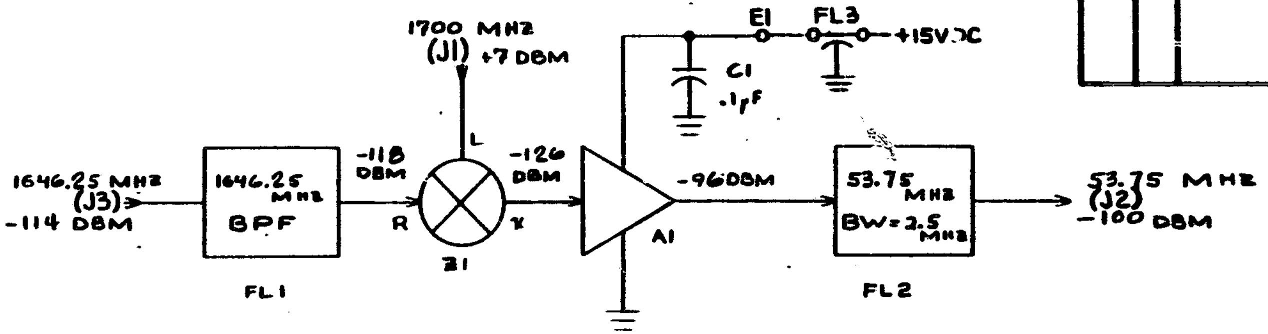

FL1 K&L 58380-1646.25/50 - P/P
FL2 K&L 3852-53.75/2.5 - P/P
Z1 ANZAC MD614
A1 WJ - A73
C1 M39014/1-1473

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LEGEND FOR PARTS LIST

ITEMS IN PARENTHESIS ARE APPLICABLE FOR AIL AND AIL SUBCONTRACTORS

☒ APPLICABLE
AR AS REQUIRED
⊟ NOT APPLICABLE
☑ ADDL MAT'L LISTED IN DOCS REQD

* VENDOR ITEM - SEE SOURCE CONTROL OR SPECIFICATION CONTROL DRAWING

MANUFACTURE IN ACCORDANCE WITH AIL SHOP PRACTICE STANDARDS 107700 UNLESS OTHERWISE SPECIFIED

REV STATUS OF PARTS						
PART NUMBER	-1	-2	-3	-4	-5	-6

-3 QTY REQD	-2	AIL STOCK NO.	CODE IDENT NO.	FIND NO.	-1 QTY REQD	PART OR IDENT NO.	NOM OR DESCR	SPEC/MATL	SYM/NOTES

PARTS LIST

PART NO.	NEXT ASSY	USED ON
–	562879-1	
–	562859-1	
	APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES	UP TO 6	ABOVE 6 TO 24	ABOVE 24
2 PL	±.02	±.03	±.06
3 PL	±.010	±.015	±.031
FRAC	±1/32	±1/16	±1/8

MATERIAL:

CONTR NO.
DR BY COLOTTI
CHK BY
REVIEW
ENGINEER FASS 12/4/79
APPROVAL (PROJ) [signature] 12/5/79
APPROVAL (GOVT)

AIL a division of CUTLER-HAMMER DEER PARK, NEW YORK 11729

SCHEMATIC DIAGRAM DOWN CONVERTER

SIZE B | CODE IDENT NO 00752 | 562861

SCALE — | SHEET OF

UNIT 1061/106

AIL-F-383-83

Figure 3-4 Receiver Module Drawing No. 562861

3-12

Image Rejection:	50 dB min.
Transmitter Frequency Rejection	50 dB min.
VSWR (Input/Output)	1.5:1 max.
Output Compression Point: (1 dB)	+5 dBm

The Receiver consists of a 1646.25 MHz bandpass filter which provides rejection to the transmitter frequency and also the image frequency. The input 1646.25 MHz signal is downconverted to 53.75 by mixing with a 1700 MHz LO. The downconverted output is amplified and fed to a bandpass filter to establish the required 2.5 MHz channel bandwidth. The IF output is fed by cable to the Receiver Processor located in the module subsystem.

The Receiver Module consists of an aluminum chassis which houses the downconverter PC board. The DC voltage interface is made through an RFI filtercon.

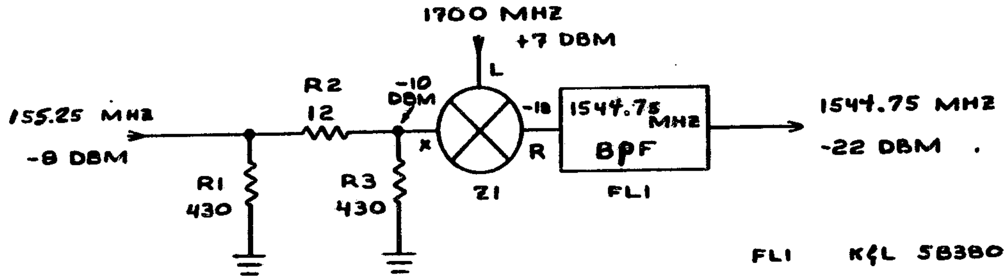
3.1.1.6 Transmitter Module

Schematic (Up-converter)	562876	Figure 3-5
Schematic (Power Amplifier)	562884	Figure 3-6

REV A 562876

THIS DRAWING INCOMPLETE WITHOUT ECN'S

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVAL
	–	PRELIM ISSUE	11-7-79	W. Johnson
	A	ISSUED WITHOUT CHANGE	8-18-86	W. Johnson



FL1 K&L 5B380-1544.75/50-P/P

Z1 MD 614

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LEGEND FOR PARTS LIST

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☒ APPLICABLE — AR AS REQUIRED

⊟ NOT APPLICABLE — ☑ ADDL MATL LISTED IN DOCS REQD

* VENDOR ITEM - SEE SOURCE CONTROL OR SPECIFICATION CONTROL DRAWING

MANUFACTURE IN ACCORDANCE WITH AIL SHOP PRACTICE STANDARDS 107700 UNLESS OTHERWISE SPECIFIED

-3	-2	AIL STOCK NO.	CODE IDENT NO.	FIND NO.	-1 QTY REQD	PART OR IDENT NO.	NOM OR DESCR	SPEC/MATL	SYM/NOTES
QTY REQD									

PARTS LIST

PART NO.	NEXT ASSY	USED ON
—	562874-1	
APPLICATION		

REV STATUS OF PARTS						
PART NUMBER	-1	-2	-3	-4	-5	-6

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES	UP TO 6	ABOVE 6 TO 24	ABOVE 24
2 PL	±.02	±.03	±.06
3 PL	±.010	±.016	±.031
FRAC	±1/32	±1/16	±1/8

MATERIAL:

CONTR NO.
DR BY COLOTTI
CHK BY
REVIEW
ENGINEER FASS
APPROVAL (PROJ)
APPROVAL (GOVT)

AIL a division of CUTLER-HAMMER

SCHEMATIC DIAGRAM UP CONVERTER

SIZE B | CODE IDENT NO 00752 | 562876

SCALE | SHEET OF

AIL-F-361-83

Figure 3-5 Transmitter Module (Up-Converter) Drawing No. 562876

3-14

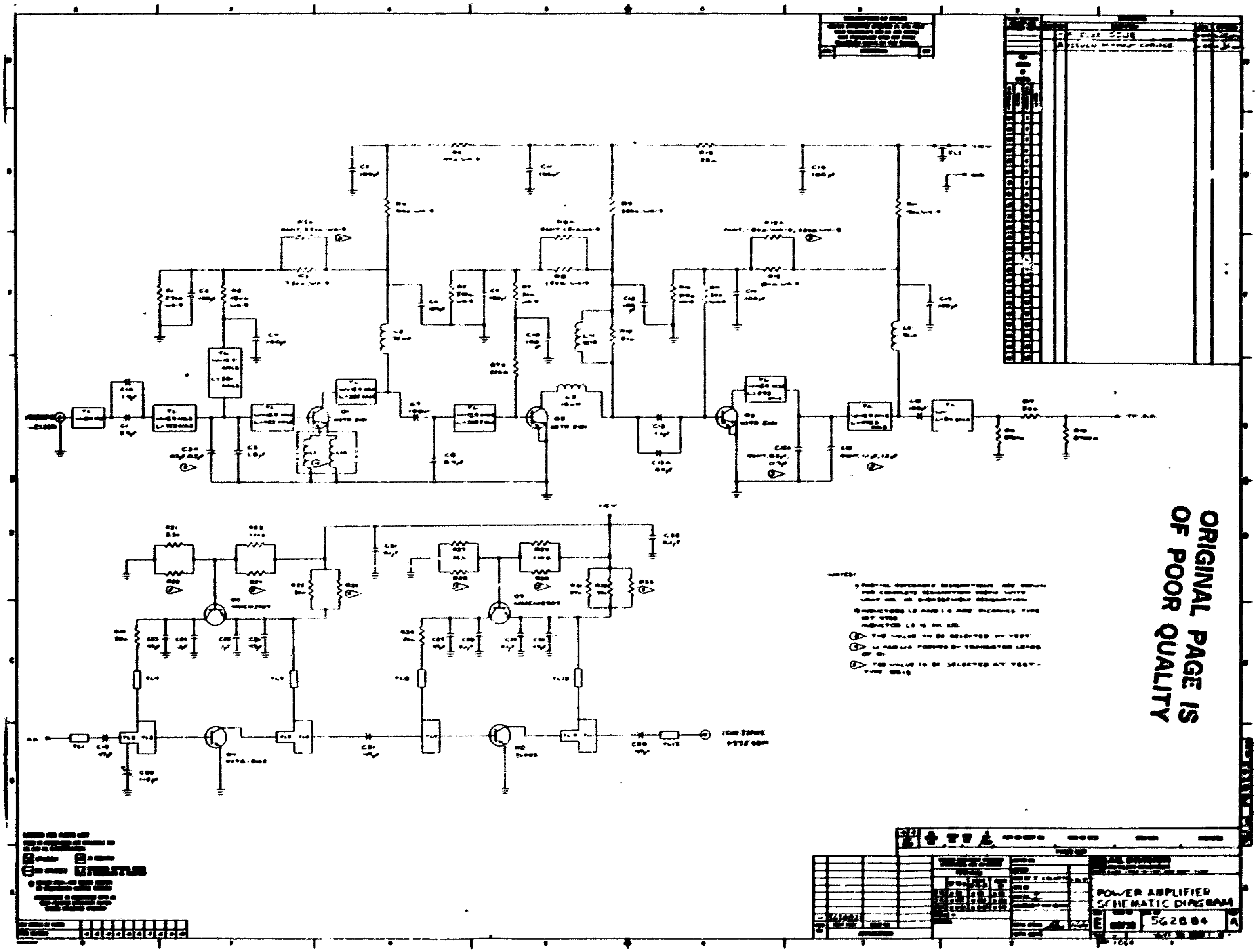

Figure 3-6 Transmitter Module (Power Amplifier) Drawing No.562884

(located in the module subsystem) and upconverts it to the transmit frequency at the required transmit power. Sufficient filtering is provided to ensure that the output power amplifier thermal noise is the sole contributor to the output noise at the receiver frequency. The Transmitter characteristics are as follows:

Input Frequency:	155.25 MHz nominal
Output Frequency:	1544.75 MHz nominal
Output Power:	+27.5 dBm
Gain:	35.5 dB min.
VSWR (Input/Output)	1.5:1 max.
Third Order IMP:	-20 dBc min.

The 155.25 MHz signal is upconverted to 1544.75 MHz by mixing with a 1700 MHz LO. The upconverted signal is filtered and amplified by a 5-stage class A power amplifier. The amplifier output power level is at +27.5 dBm and is fed to the transmitter portion of the Diplexer.

The Transmitter Module consists of two compartments which house the upconverter PC board and power amplifier PC board.

3.1.1.7 X10 Multiplier

The X10 Multiplier generates the LO required by each of the antenna modules. The LO is used for the receiver downconversion and the transmitter upconversion. The LO frequency is coherent to a reference standard housed in the module subsystem. The Multiplier characteristics are as follows:

Input Frequency:	170 MHz nominal
Input Power:	-3 dBm min.
Output Frequency:	170 MHz
Output Power:	+30 dBm min.
Spurious Outputs:	-60 DBc
Harmonic Outputs:	-10 DBc
Input/Output VSWR:	2:1 max.

The Multiplier receives a 170 MHz input signal from the module subsystem frequency source. The input signal is multiplied by ten by a step recovery diode to produce 1700 MHz. The 1700 MHz signal is filtered and amplified to an output power level of 1.0 watt. The 1 watt output signal is fed to a 64-way divider which consists of nine (9) eight-way power dividers. The 64 outputs from the divider network are used as LO's for the antenna modules.

Semirigid coaxial cable is used for connections between the Multiplier, power Dividers and the antenna modules.

3.1.2 Module Subsystem

The Module Subsystem includes all signal processing and data processing subsystems required to meet the performance specification for the AMPA Experimental Communications System. The module subsystem consists of the following six (6) rack mounted drawers:

- Receiver Processor
- Transmitter Processor & Frequency Source
- Signal Processor
- Dedicated Experiment Processor
- Modem
- Power Conditioner

3.1.2.1 Receiver Processor

The 32 received signals from the array subsystem are split to form two (2) groups of 32 signals. Independent weighting is applied to each signal so as to produce two independent beams. The Receiver Processor characteristics are as follows:

Frequency:	53.75 MHz
Bandwidth	2.5 MHz
Dynamic Range:	40 dB
Weighting Networks:	0 - 360° phase settings and 0 - 20 dB amplitude settings
Pre-Weighted Sampled Output:	1 us per output

3.1.2.2 Transmitter Processor and Frequency Source

The Transmitter Processor accepts LO's from the frequency source and modulated signals from the modem and provides 32 IF outputs to the array subsystem for subsequent transmission. Independent weighting is applied to each signal so as to provide the beam forming function required. The Transmitter Processor and Frequency Source characteristics are as follows:

Input Frequency:	30 MHz
Output Frequency:	155.225, 155.275 MHz (selectable)
Weighting Networks:	0 - 360° phase settings and 0 - 20 dB amplitude settings
Frequency Source Outputs:	30 MHz, 170 MHz, 125.225 MHz, 125.275 MHz
Frequency Stability (0° to 50°C)	$\pm 1 \times 10^{-7}$

3.1.2.3 Signal Processor

The Signal Processor performs code recognition and corrects for the Doppler shift. In addition the Signal Processor performs the correlation functions for

both beams. The Signal Processor characteristics are as follows:

Input Frequency:	53.75 MHz
Signal Processing Frequency:	30 MHz
Doppler Correction:	$\pm$38 kHz
Coarse Doppler Input:	Reduces Doppler uncertainty to $\pm$4 kHz
Correlation:	Sequential correlations for the 32 elements for both signal and interference inputs

3.1.2.4 Dedicated Experiment Processor (DEP)

The DEP performs all the algorithms required by the Experimental Model. It receives correlation inputs from the Signal Processor and outputs weighting information for both transmit and receive beam functions. The DEP also outputs coarse Doppler information to the Signal Processor. The DEP characteristics are as follows:

Conversion Time:	2.5 us (ADC - 8 bit)
Word Size:	16 bits
Cycle Time:	5 MHz (200 nsec) for arithmetic processing

3.1.2.5 Modem

The Modem demodulates the FM voice and BPSK signals received from the Signal Processor. For the transmit function the Modem accepts FM and BPSK modulation data. In addition the Modem detects and counts errors in the bit pattern on receive. The Modem characteristics are as follows:

Frequency:	30 MHz
Modulation:	FM, BPSK
FM Deviation:	15 kHz

BPSK Data Rates:	1, 2, 4, 8, 16,32 KBPS
BERT:	The BERT generates a 2047 bit pseudorandom noise code and synchronizes the received and transmitted patterns and counts the received errors

3.1.2.6 Power Conditioner

The Power Conditioner supplies all DC power for the module subsystem. The Power Conditioner characteristics are as follows:

Input Voltage:	115 VAC
Output Voltages:	+15V @ 9.3 AMPS
	-15 V @ 7.3 AMPS
	+5 V @ 31 AMPS

3.1.2.7 Receiver Processor

A block diagram of the receiver processor is shown in Figure 3-7. The receiver processor accepts the 53.75 MHz outputs of the 32 antenna modules. Each signal is split 4 ways. The split outputs feed a weighting network for Beam A, a weighting network for Beam B and two sampling switches for Beam A and Beam B. The 32 outputs from the Beam A weighting networks are summed together. Similarly, the Beam B weighting networks are summed together. The summed outputs are fed to the decoder unit which is part of the signal processor. The outputs of the sampling switches are fed to the correlators which are located in the signal processor.

The weighting networks each provide an output signal whose phase is variable over a 360 degree range and whose magnitude is adjustable over a 20 dB range. The weighting networks are adjusted by control lines from the DEP. Each channel of weighting network consist of a quad hybrid and pin diode, bi-phase attenuators for control of the real and imaginary components.

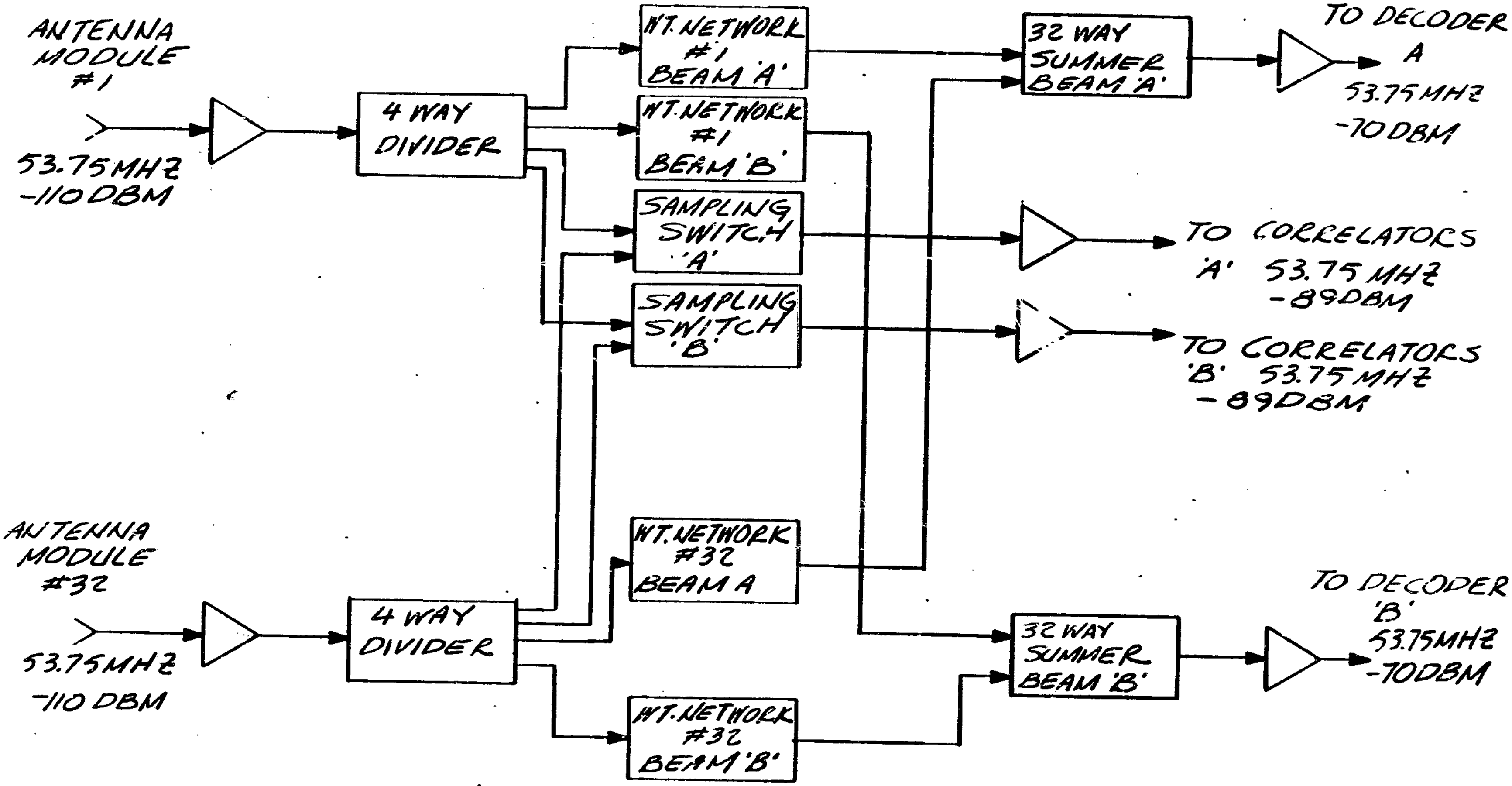

FIGURE 3-7
RECEIVER PROCESSOR
BLOCK DIAGRAM

3-23

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3.1.2.8 Signal Processor

The function of the Signal Processor is to permit acquisition of the coded transmission such that the system can be operated in a fully adaptive mode. Once acquisition is made, correlation functions are performed and the receiver processor weighting networks are updated for the adpation process.

A block diagram of the Signal Processor is depicted in Figure 3-8. The inputs to the Signal Processor consist of the SUM channel and sample channel signals from the Receiver Processor. The 53.75 MHz sum channel signal is fed through an AGC amplifier then mixed with an 83.75 MHz VCXO which is phase locked to the input. The resulting 30 MHz signal is fed to the modem unit and to the interference correlator. A detected output from the AGC amplifier provides an indication of the sum channel interference power. The signal was passed through an AGC amplifier whose functions are two fold, 1) to provide a noise reference for the code detector so to set its threshold as a function of S/N and 2) to limit the correlator dynamic range. The interference correlator is used for nulling any interferers prior to the initiation of the MSIR algorithm.

The PN generator produces a replica of the expected 63-bit code sequence. The input signal is mixed with the PN generator output sequence. When the signal and PN generator code phases are synchronized the signal energy will be despread about the 30 MHz carrier. For all other conditions the signal energy will be spread across the 2.5 MHz bandwidth and appear as noise. At synchronization, a narrow band 30 MHz CW signal will appear after the 30 MHz crystal filter. The filter output is detected and compared to a reference in a comparator. When the signal exceeds the reference a code lock indication occurs. When this occurs the phase of the PN generator sequence is held fixed.

Sufficient processing gain must be provided in the signal processor to enable code acquisition. The processing gain required is determined by calculating the expected SNR at the code detector due to the transmitted power, range losses, doppler losses and antenna array gain. This processing gain is achieved by using a narrow 8 kHz bandpass filter centered at 30 MHz to pass the collapsed coded signal. The SNR is effectively improved by the ratio of the RF to IF bandwidths namely 2500/8 = 312.5 or 24.9 dB. This processing gain is sufficient to achieve the required SNR for a 95% probability of intercept and a 10^{-4} false alarm rate. This improvement requires 4 code epochs.

The receiver code is stepped in 1/2 chip steps and mixed with the incoming received coded signal. When the two codes are coincident in phase, the received spectrum is collapsed to CW and thresholded. However, there can be threshold noise firings or detection of code side lobes since partial despreading occurs at these points. To reduce the probability of false alarm, a narrow sampling window of .5 μSec was generated 2 μSec prior to shifting the code to the next epoch. In addition, two threshold crossings are required to stop the code with the second threshold crossing occurring 1/2 Bit delayed from the first. This criteria when passed will stop the code from shifting and switch control to a delay lock loop. The delay lock loop compares the outputs of N-1 and N+1 code bit delays and controls the frequency of the PN generator which allows the stepped code to track the received code phase as the array FOV changes.

The crystal filter output is also fed to an AGC amplifier. A detected output from the AGC amplifier provides an indication of the desired signal power. The AGC amplifier output is fed to one side of the signal correlator.

The 53.75 MHz pre-weighted sample channel input is mixed with the 83.75 MHz VCXO to result in 30 MHz. This signal is fed to the interference correlator. The sample channel signal is also mixed with PN generator output and the resulting signal is fed to the other side of the signal correlator. The in-phase and quadrature phase outputs from the correlators interface with the DEP.

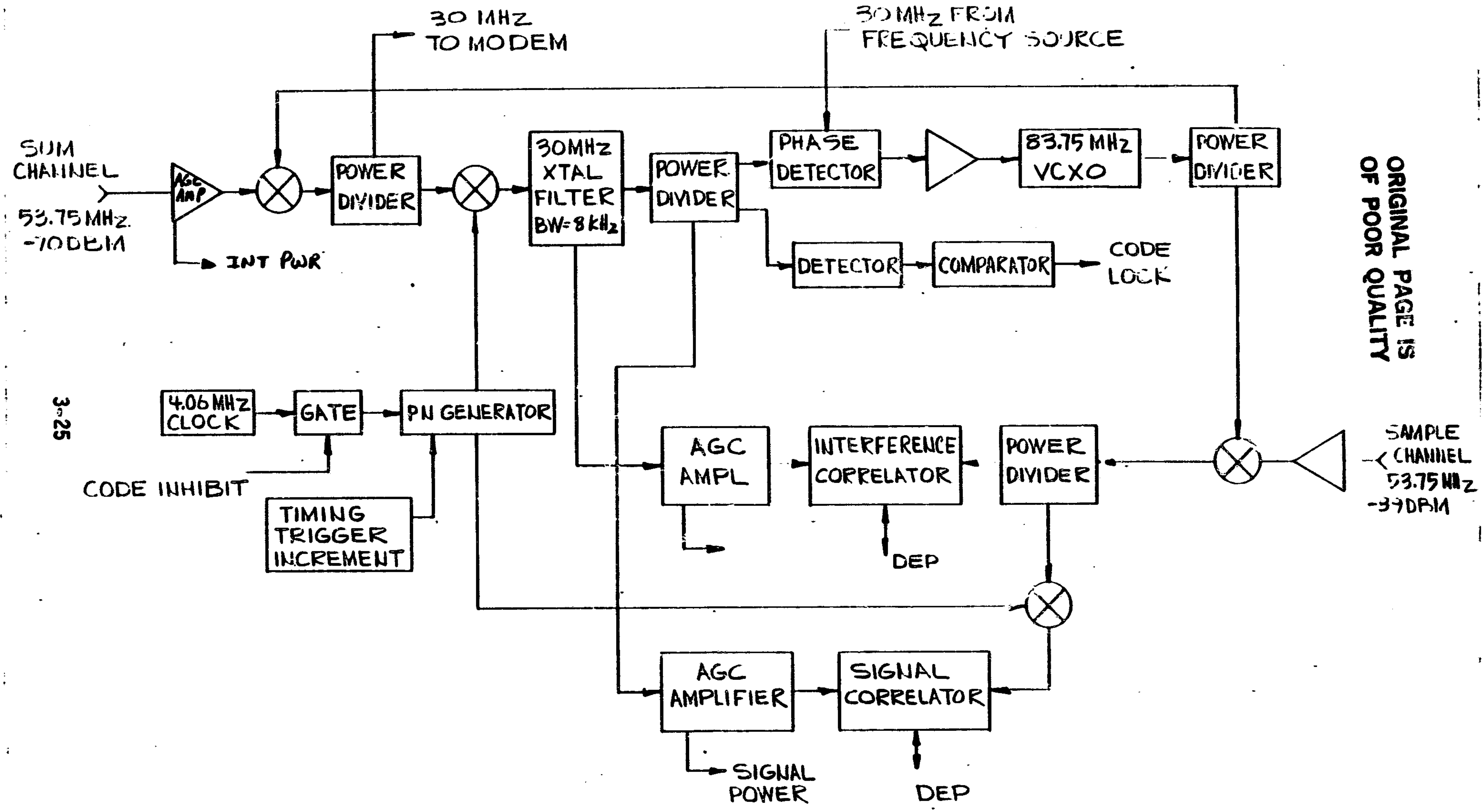

FIGURE 3-8 SIGNAL PROCESSOR BLOCK DIAGRAM

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3.1.2.9 Dedicated Experiment Processor

The DEP provides two (2) separate and independent beam functions. That is separate logic circuitry will service Beam A transmit and receive and the other set Beam B transmit and receive. Figure 3-9 is a block diagram of one beam set. A set of logic circuits contained in two boards, Star A and Star B. STAR A consists of a CPU and microcontroller. The rest of the circuitry is contained on board STAR B .

Operation of each beam can be described as follows. There are eight (8) modes of operation. They are calibration, acquisition, coarse geolocation, fine geolocation, track, transmitter pointing, receiver pointing and self test. The Host computer, PDP 11/34, interfaces asynchroneously with the input FIFO with a mode message. The mode message will consist of a control word (defines mode) and the various data inputs that the DEP will require. At the end of the message the Host will raise an interrupt to tell the DEP microcontroller that the input FIFO contains a message. The DEP then loads the input message into the input RAM which is contained in the CPU. The firmware which is part of the microcontroller then runs the required program or algorithm.

The detailed operation of the 8 programs are described in Section 4.3. When external data is required, for example, correlations, the Data Acquisition Subsystem (DAS) is enabled by the firmware. Here the signals from the Signal Processor are sampled and converted to digital data. This data is then loaded into the input RAM of the CPU. When the computations are completed the output CPU RAM data are sent to output buffers; the Transmit Processor drivers to enable the transmit weights, the Receiver Processor to control the code matching and Doppler locking. In addition, the data is sent to an output FIFO for transmission to the Host computer. The DEP generates an interrupt to the Host telling it that data is ready to be read out.

Two additional hardware circuits have been included in the DEP to allow simultaneous operation of some firmware tasks with overall system operation. These circuits are the 16 msec interrupt for Doppler lock and the 2 second interrupt for track. These circuits are used to detect the presence of valid acquisition operation and track respectively.

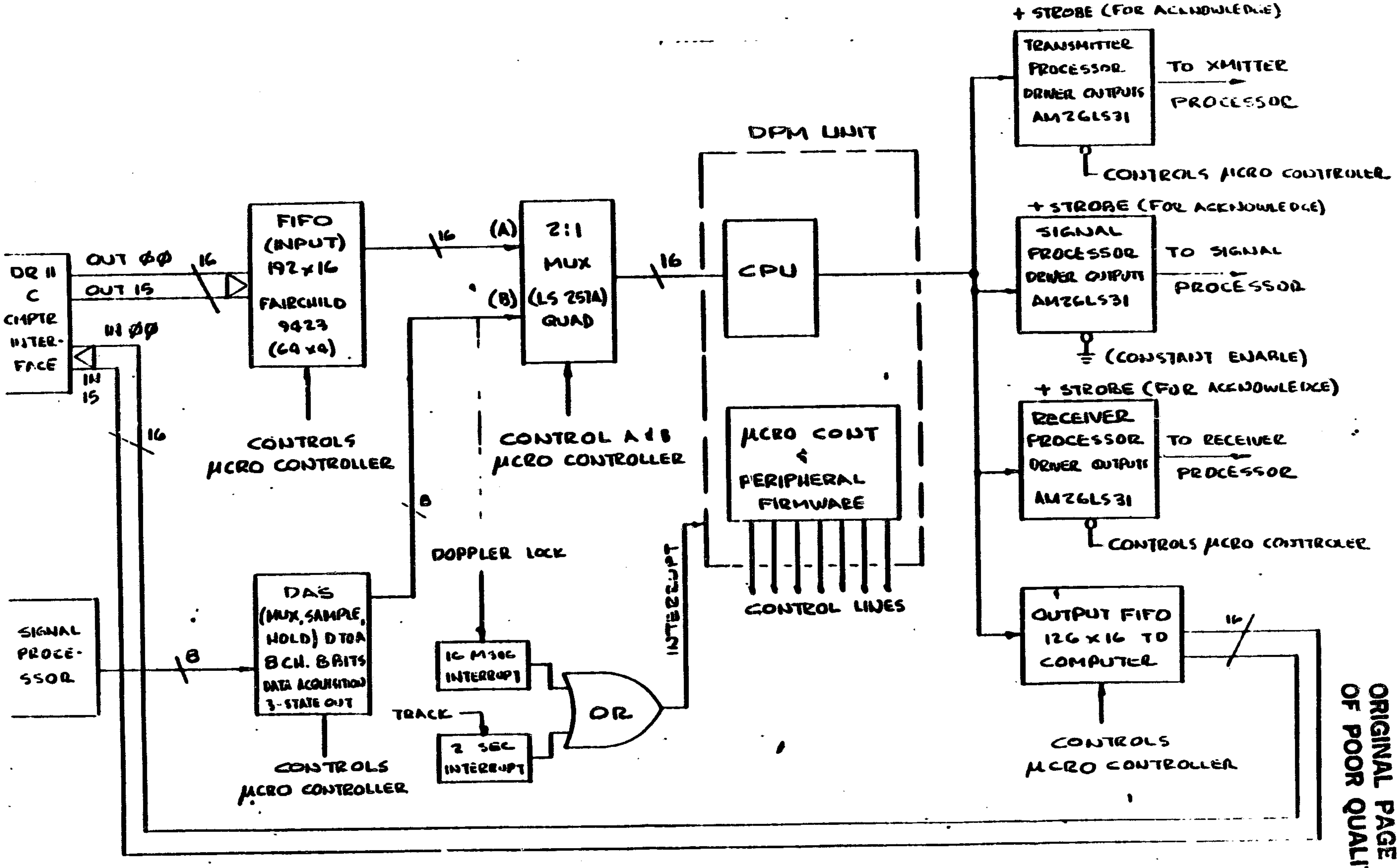

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Figure 3-9 Block Diagram DEP (One Beam)

1-89

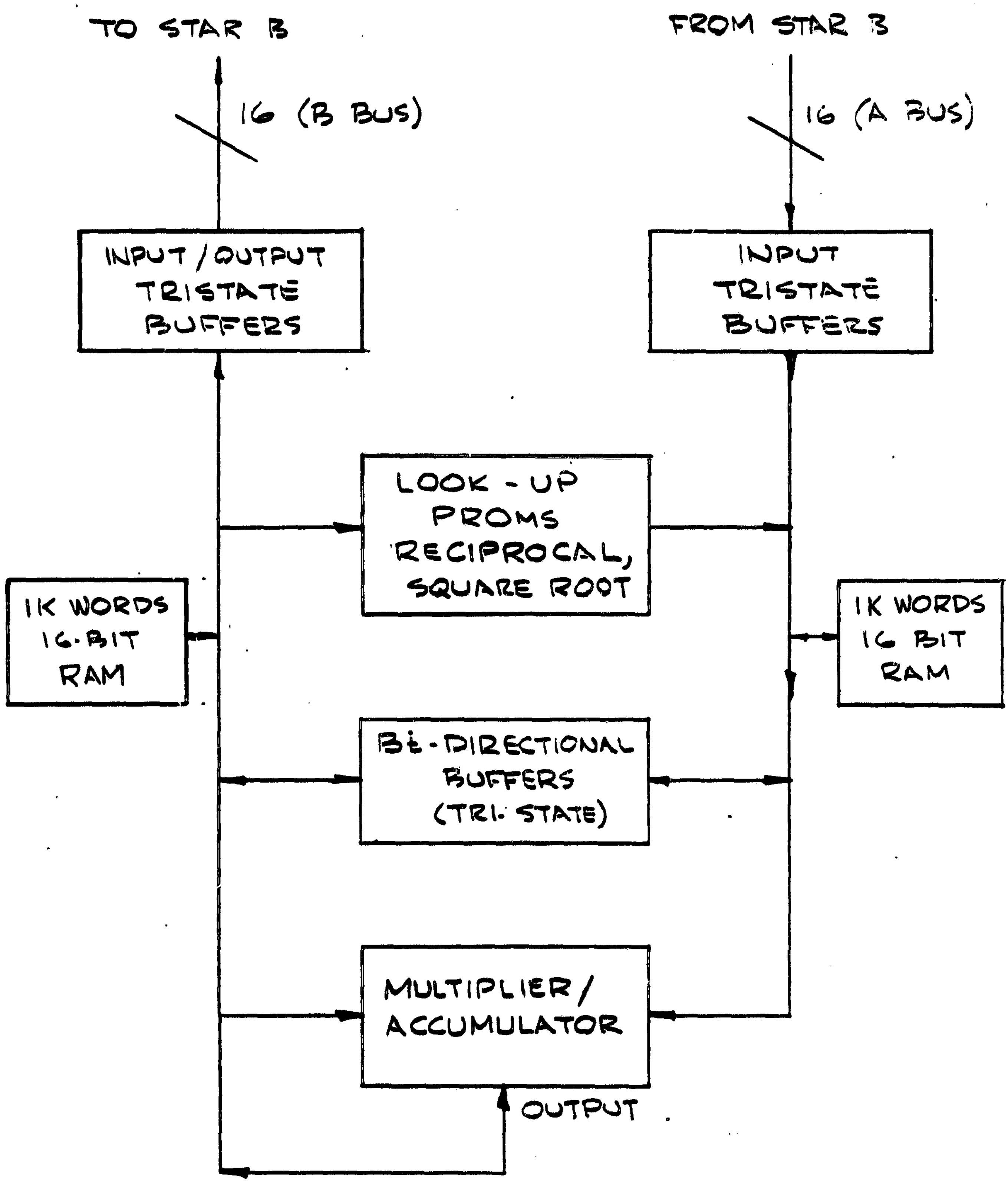
3.1.2.10 STAR A

The STAR A unit provides the mathematical conversions and controls for the DEP. It receives a 16 bit (2's compliment) data word from STAR B and implements the necessary mode of operation. The STAR A generates a 64 bit word which provides internal control lines for a microcontroller, RAM memory, a multiplier-accumulator, look-up PROM's and I/O buffers. It also provides a 24 bit word control to STAR B. The STAR A unit generates the resultant computations in a 16 bit data word format and sends the data with their associated control signals to the STAR B.

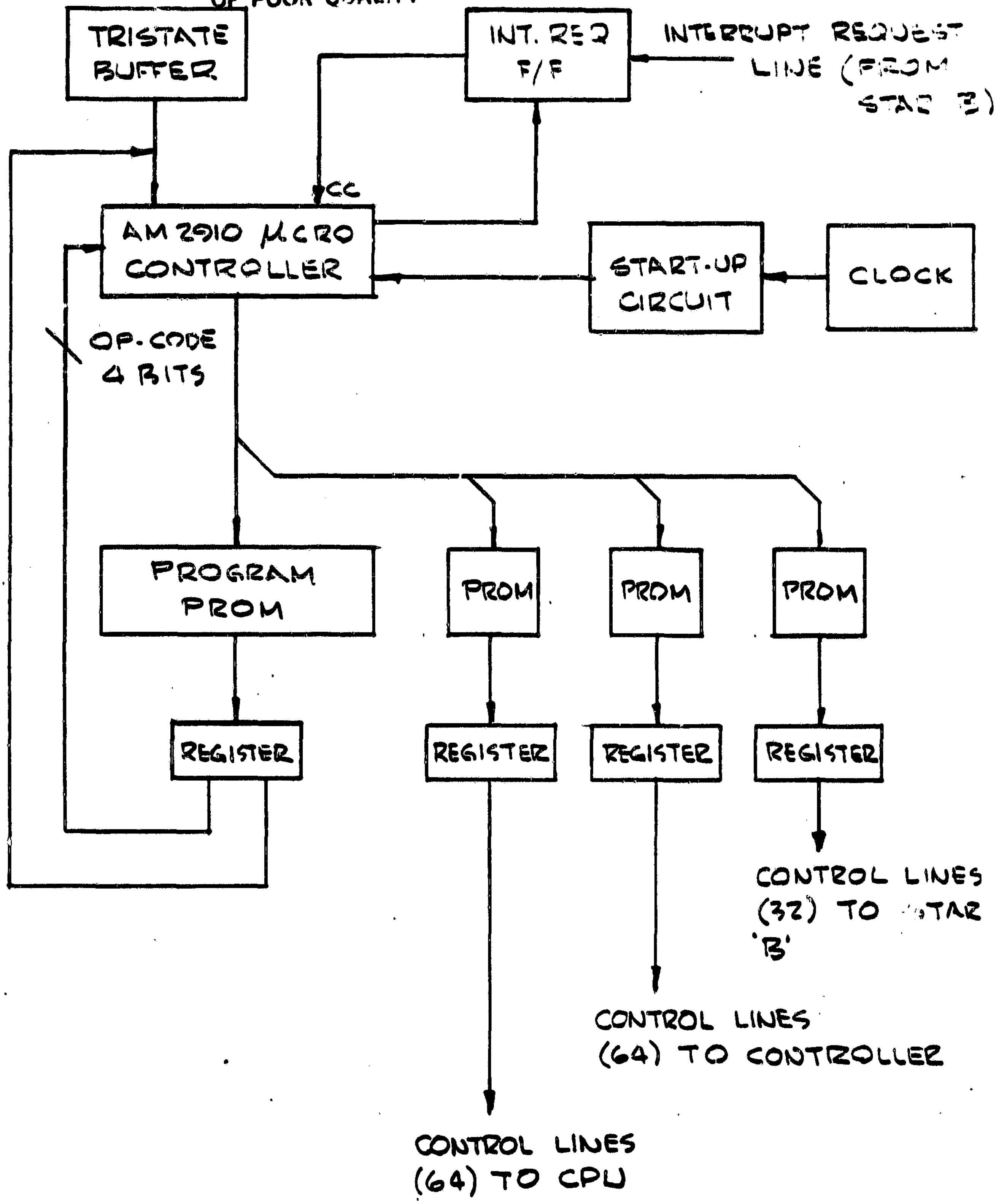
The STAR A unit consists of two (2) discrete circuits: 1 - the CPU (Central Processor) and 2 - the Controller.

The CPU architecture is shown in Figure 3-10. It consists of various tri-state function blocks which control the direction of two 16 bit data buses (BUS A, B). The data from STAR B is sent to the "B" bus and then loaded into RAM. Each RAM block is 1K deep by 16 bits wide. Look-up tables for reciprocal and square root functions are provided by PROM's to shorten algorithm time in performance of the DOT Product. The CPU's Arithmetic Logic Unit (ALU) is generated by use of a Multiplier-Accumulator(TRW 1010J). It is capable of 16 x 16 bit multiplication and product accumulation (add, subtract, rounding of resultant, accumulate). The numerical system is designed for 2's compliment arithmetic. Pipe line design enables a resultant (35-bit width) to occur at the output of the Multiplier-Accumulator every CPU cycle (200 nansec). The resultant may be stored in RAM memory or transmitted directly to Bus A and then to the STAR B unit.

Controller circuitry is shown in Figure 3-11. It consists of an AMD-2910 microcontroller (Advanced Micro Devices, Inc.), PROM's (firmware functions) and registers for storage. The AMD Microcontroller generates a 10-bit program address based on the 4-bit Op code. It is capable of performing 16 different sequence control instructions including conditional branching to any one of its 4K micro word range.


TO STAR B
FROM STAR 3
16 (B BUS)
16 (A BUS)
INPUT / OUTPUT TRISTATE BUFFERS
INPUT TRISTATE BUFFERS
LOOK - UP PROMS RECIPROCAL, SQUARE ROOT
1K WORDS 16-BIT RAM
1K WORDS 16 BIT RAM
BI-DIRECTIONAL BUFFERS (TRI-STATE)
MULTIPLIER / ACCUMULATOR
OUTPUT

CPU FIG. 3-10



CONTROLLER FIG. 3-11

Four of the instructions are unconditional. Their effect depends entirely on the interpretation of the instruction. Ten of the instructions have an effect which is partially controlled by external data dependent conditions. The microcontroller gives the program looping capability (a loop that can be iterated up to 4K times), while an internal register/counter keeps track of the number of iterations generated.

Branching may be predicatedupon the result of a condition code test, thus providing algorithm adaption while the execution of the program is in progress. The interrupt request (generated from STAR B) causes a conditional code message, which transfers program control to the address specified in the data field.

Program control may also be transferred to any one of 16 selected addresses by means of a 4 bit external code (DO 12-15).

A start up circuit ensures the proper clock phases and sets the address bus for program PROM to its higher address (all 1's) while disabling the output of the AMD 2910. This causes the instruction in highest PROM program location to be accessed, which vector the program to a specified starting address.

The controller operates at a maximum of 5 MHz (200 nanosec) clock frequency, taking one complete cycle for writing into or reading out of RAM. The access time of the PROM's are within 1/2 cycle of the clock frequency.

3.1.2.11 STAR B

The "STAR B" unit interfaces with the Host computer (through DR11-C interface), STAR A, Transmitter Processor, Receiver Processor and Signal Processor units.

It receives command and data word formats from the Host computer. The "STAR B" also accepts data information (7 discrete analog signals) from the Signal Processor. STAR "B" sends the weights and controls which were computed by STAR "A" to the Transmitter and Receiver Processors. The STAR B unit also transmits coarse doppler data, code inhibit, threshold levels and correlator dump control signals. It also receives track and lock indicator signals from the Signal Processor.

The STAR B unit transmits (Figure 3-12) a set of data weights. Each set consists of 64 weights in a 17-bit word configuration. The word configuration is the following:

8 bit weight data in 2's compliment notation

6 bit address for weights in true binary (unsigned) notation

Enable line for weight decoder

Final strobe for latching set of weights (64)

Frequency selection

STAR B transmits 2 sets of data to the Receiver Processor. One (1) set of data (weights) is transmitted in the same manner as described above (frequency selection omitted). The second set of data consists of the sampling switch addresses (5 bits) and its associated strobe.

The Signal Processor receives an 8-bit coarse Doppler word, 1 bit for Doppler strobe, 1 bit for code inhibit, 2 bits for threshold levels, and 1 bit for correlator dump.

The STAR B unit stores the desired signal power, interference power and the Doppler frequency in a FIFO memory, then transmits the information to the Host computer for further analysis. The selection of one of the data transfers is determined by the control bus generated from the STAR A unit.

The STAR B receives (Figure 3-13) 16-bit words (mode message and associated data) and a strobe from the PDP 11/34. The data is "dumped" into a FIFO (first in-first out) memory which is 192 words deep by 16 bits wide.

STAR B also receives 7 analog inputs from the Signal Processor. The STAR A control bus switches in the analog data which is converted to a digital word through STAR A's firmware designation. The analog-to-digital conversion is accomplished through an 8 bit analog multiplexer, sample and hold circuit and finally, an A to D converter. The FIFO and D/A are multiplexer for selection and transmitted to the STAR A for computation. The selection of data to be computated is determined by the control bus.

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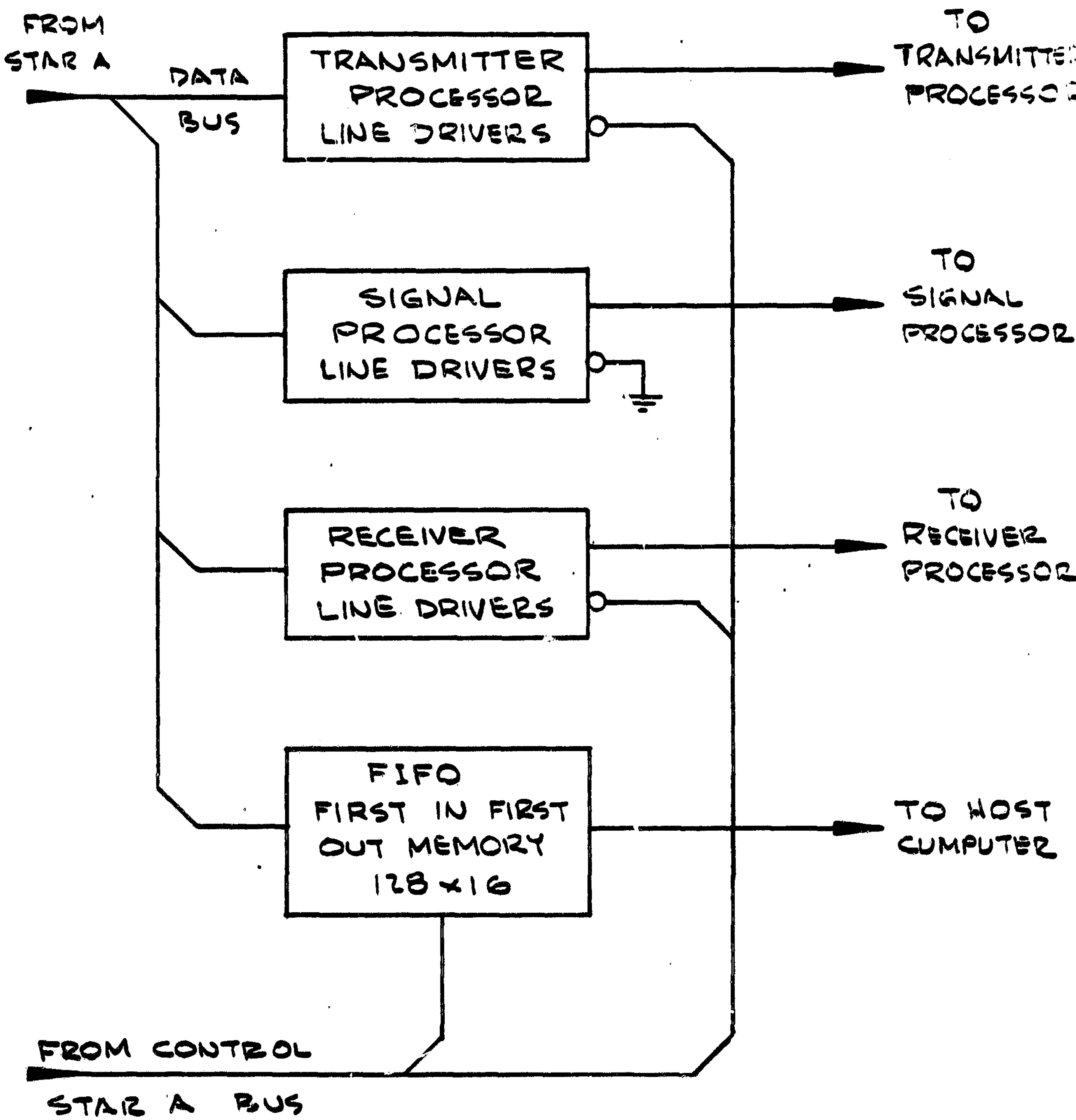
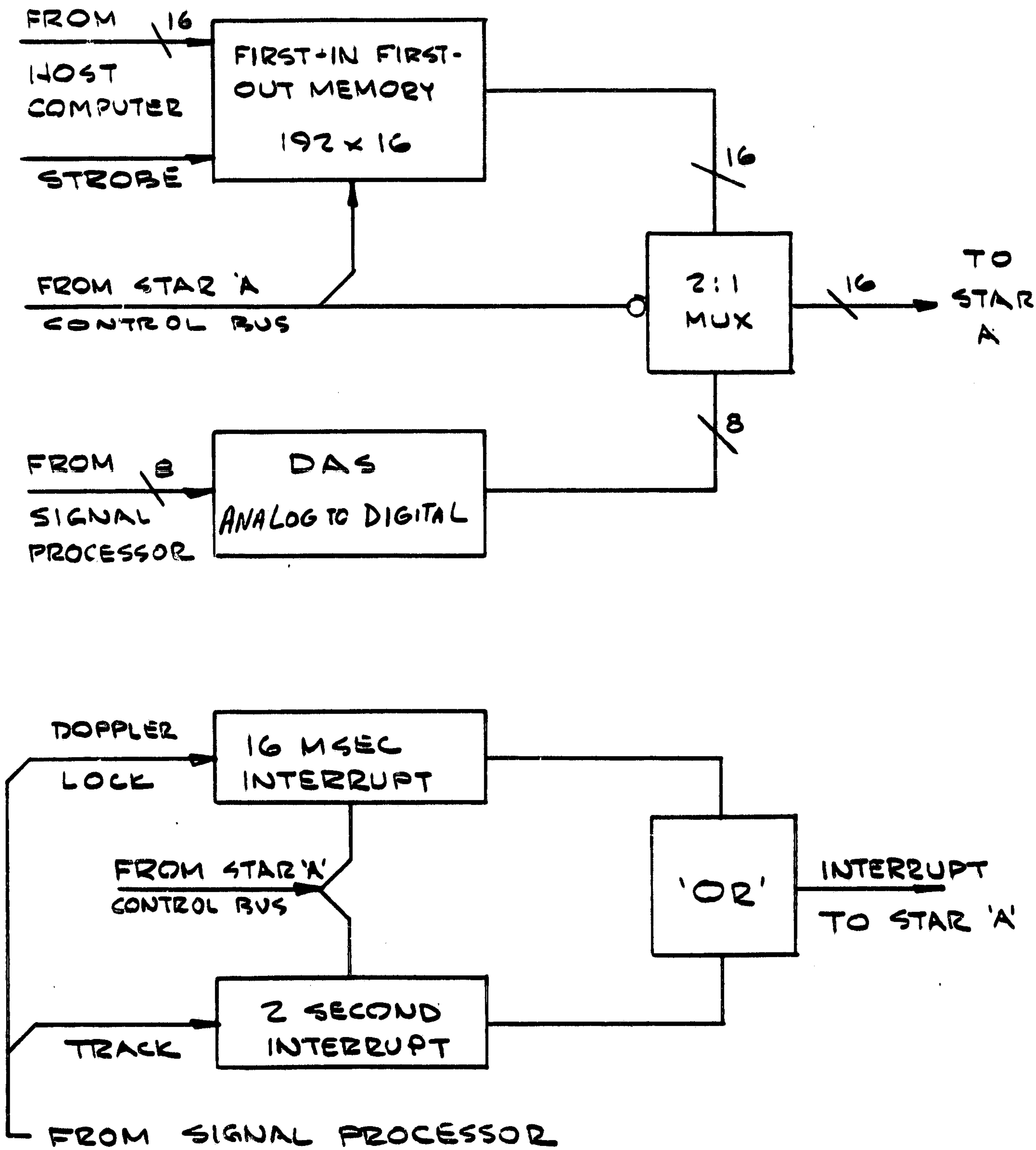


STAR B FIG. 3-12



STAR 'B' FIG 3-13

A synchronous 16 millisec timer is used for acquisition mode. If the Doppler lock signal (after negation of code inhibit has been generated) has not been received within 16 milli-sec, an interrupt is generated.

A synchronous 2 second timing circuit is used for the track mode. If the track signal has dropped out for 2 seconds, an interrupt occurs.

3.1.2.12 Modem

A functional block diagram of the modem unit is shown in Figure 3-14. In the received mode, the modem unit accepts the 30 MHz signals from the signal processor. The received command word determines the mode of operation. (BPSK or FM). The modem demodulates both FM voice and BPSK data from the received signal. It also accepts data for modulation on the transmit beams. Configuration switching to provide "bent pipe" mode capability (received signal transmitted without demodulation) and other modulation combinations (BPSK modulation to FM internal; FM modulation to BPSK internal and external modulations). The bit error rate measurement equipment is also included in the modem unit.

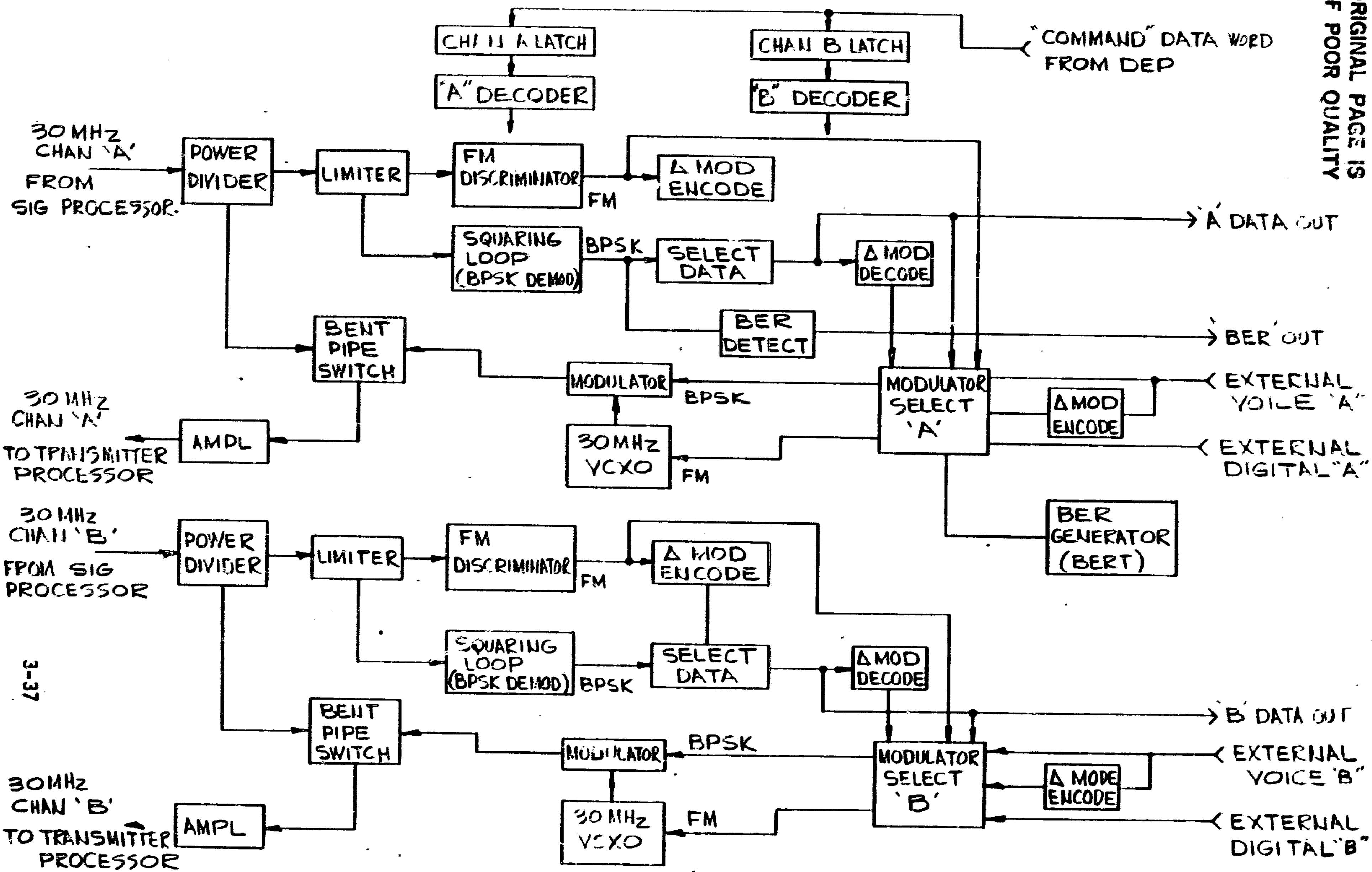


FIGURE 3-14 MODEM BLOCK DIAGRAM

3.1.2.13 Transmitter Processor

A block diagram of the transmitter processor is shown in Figure 3-15. The transmitter processor's function is to accept the two modulated 30 MHz outputs from the modem unit and form the two independently steered transmit beams. The input signal is upconverted to 155.25 MHz with an LO received from the frequency source. The LO frequency is selectable and is either 125.225 MHz or 125.275 MHz. The resulting upconverted output is filtered and amplified and fed to 32 weighting networks. The weighting networks are similar to the weighting networks used in the receiver processor. The weighting networks provide the pointing and shaping functions for the transmitted beam. Thirty-two summers are used to sum the corresponding Beam A and Beam B weighting network outputs. The summed outputs are then fed to the 32 transmitter sections of the antenna modules.

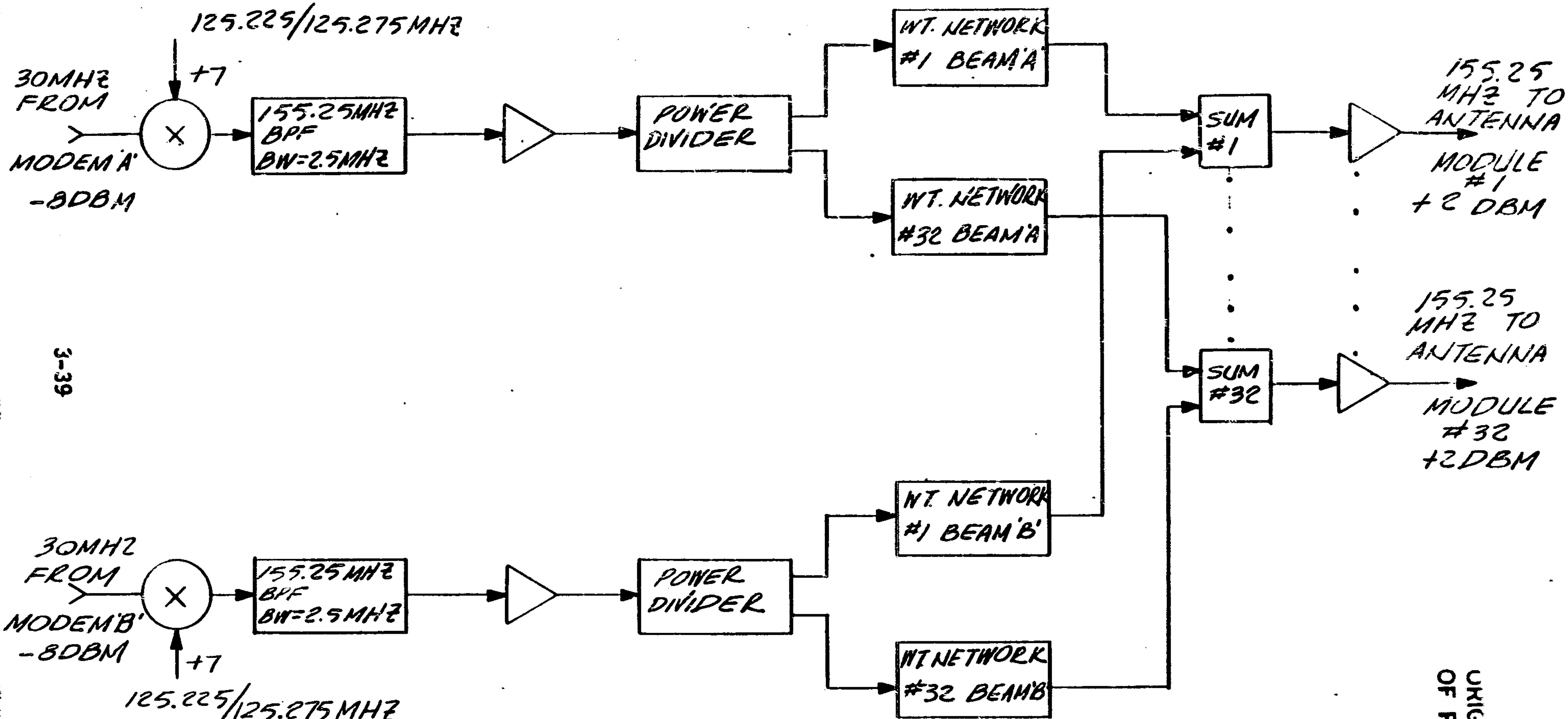


FIGURE 3-15
TRANSMITTER PROCESSOR
BLOCK DIAGRAM

3.1.2.14 Module Frequency Source

A block diagram of the Module Frequency Source is illustrated in Figure 3-16. All frequencies generated are coherent to a 10 MHz Temperature Compensated Crystal Oscillator (TCXO). The frequencies generated are 30 MHz, 170 MHz, 125.225 MHz and 125.275 MHz. The 30 MHz signal is used by the signal processor to perform a phase comparison to lock the doppler loop. The 170 MHz signal is used for the array frequency source. The 125.225/125.275 MHz signal is used as an LO in the transmitter processor.

The 10 MHz TCXO output is fed to a comb generator whose output is filtered to produce the 30 MHz and 170 MHz output signals. The 10 MHz output is also divided down to produce 2.5 kHz which is required to make a phase comparison in the 125.225/125.275 MHz phase locked loops. The phase locked loops utilize a programmable divider which enables the output frequency to be selectable.

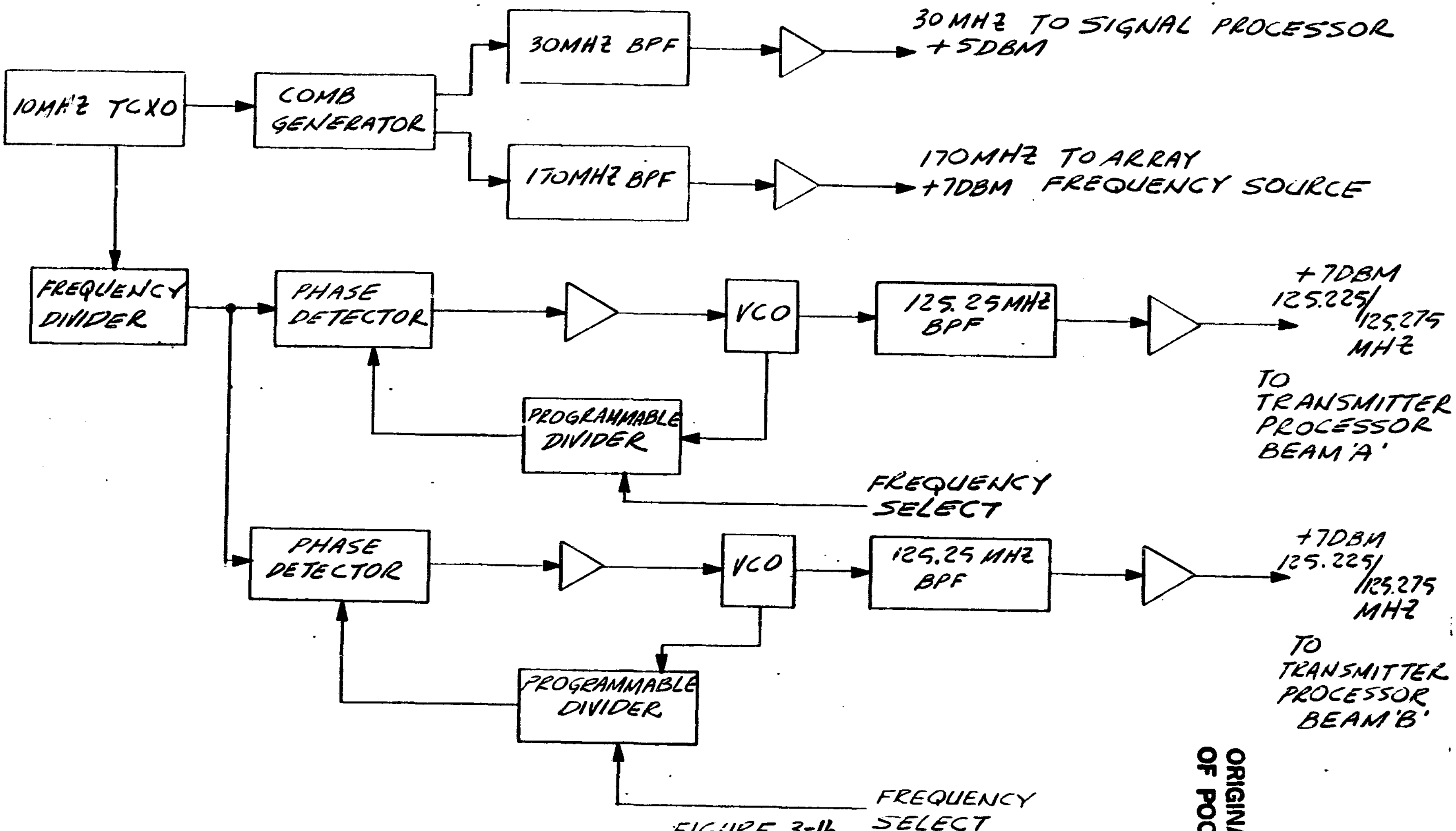


FIGURE 3-16
MODULE FREQUENCY SOURCE
BLOCK DIAGRAM

3-41

3.2 STE System

The Special Test Equipment (STE) consists of the following subsystems:

RF Scenario

RF Manual Test Rack

STE Mgt. System

The RF scenario consists of four (4) User Terminal Simulators, two (2) Interference Sources and six (6) Parabolic Dish Antennas. An antenna is provided for each User Terminal Simulator and Interference Source. A linear polarized field probe antenna which is rotatable was used to evaluate plane wave conditions in the test range. The major functions of the User Terminal Simulator are:

- Provide sufficient EIRP to simulate a 53 dB-Hz link to the Experimental Model.
- Receive and process signals from the Experimental Model.
- Operate in receive and transmit modes simultaneously.
- Modulate and demodulate BPSK and FM data.
- Provide a unique user code for the adaptive models.
- Provide Bit Error Rate measurements to evaluate link performance.

Table 3-1 summarizes the characteristics of the User Terminal Simulator.

The RF manual test rack provided the capability for testing the array subsystem without the module subsystem attached. This was used during preliminary testing of the array subsystem to evaluate the beam forming and pointing capability of the array.

The STE Mgt. system consists of a computer and peripheral equipment which is used to operate and control the Experimental Model during the system testing phase.

Table 3-1 User Terminal Simulator Characteristics

A. Receiver	
Center frequency	Channel A: 1544.725 MHz (nominal) Channel B: 1544.775 MHz (nominal)
Bandwidth, IF	2.5 MHz for spectrum monitoring, 50 kHz for data demodulation
Image rejection	100 dB
LO leakage	-145 dBm
Spurious response	-70 dB
Dynamic range	35 dB
Demodulator, analog	FM limiter - discriminator provides at least 40 dB range of limiting prior to 40 kHz peak-to-peak discriminator. Output per MIL-STD-188B, paragraph 3.4.2. Frequency response is 50 Hz to 4 kHz
Demodulator, digital	BPSK demodulation of Doppler corrected data. Data rates from 1 to 32 kBps. Output per MIL-STD-188B, paragraph 3.2.4.1.1
Decoder, digitized voice	Decodes delta modulated voice to reconstruct analog signal. Output per MIL-STD-188B, paragraph 3.4.2
B. Transmitter	
Center frequency	Channel A: 1646.225 MHz Channel B: 1646.275 MHz
Frequency stability	$\pm 5 \times 10^{-8}$ over temperature range
Type	Class A amplifier, all solid state
Power Output	+19.5 dBm,minimum for data +13.5 dBm, minimum for code
Bandwidth	2.5 MHz, minimum
Spurious output	-80 dBc
LO leakage	-145 dBm
Harmonic output	-80 dBc

Table 3-1 (continued)

B. Transmitter (cont)

Protection	Infinite VSWR protected
Modulation, analog	NBFM. Peak deviation of $\pm$15 kHz. Voice input 50 to 4000 Hz per MIL-STD-188B, paragraph 3.4.2
Modulation, digital data	BPSK at rates from 1 to 32 kBps External or internal (encoded voice or PN code)source
Modulation, digital code	QPSK. Combined 2 MBps code and digital data (1 to 32 kBps) in BPSK form on phase quadrature carriers
Voice encoder	Encode analog voice to delta modulation format at 32 kBps rate
Code generator	63-bit nonmaximal length sequence, greater than 10 dB orthogonality. Bit rate 2.03 MBps Octal 147

C. BERT

Code type	2047-bit PN sequence
Bit Rate	1 to 32 kBps, external clock
Bit synchronizer	Included
BER/range	10^{-1} to 10^{-5}
Data block size	10^{1} to 10^{6}
Error display	0 to 999
Overrange	LED indicator

3.2.1 RF Scenario System

The RF Scenario System is comprised of the RF Interference Source/Switch Matrix and four (4) User Terminal Simulators which interfaces with seven (7) antennas; four (4) User Terminal antennas, two (2) RF Interference Source antennas and one (1) Field Probe antenna. It also includes a Data Processor, a Spectrum Analyzer and a Control & Status Interface Assembly.

The antennas have 20 dB gain. The minimum EIRP for each User Terminal Simulator is -39.5 dBm.

The RF Scenario consists of the following units:

Receiver/Transmitter Drawer

Control Drawer

RF Interference Source

Data Processor

Spectrum Analyzer

Control & Status Interface Assy.

3.2.1.1 Receiver/Transmitter Drawer (Interconnection Diagram 563416) Figure 3-17

The receiver consists of a diplexer, a low noise preamplifier, bandpass filter, mixer, IF filter and amplifier. The preamplifier has a noise figure of 2.5 dB maximum and a gain of 30 dB minimum. There is sufficient gain to prevent the following stages from contributing more than a 0.5 dB to the system noise figure. The bandpass filter reduces transmitter leakage power to the first mixer. The local oscillator is at a frequency of 1725.5 MHz, resulting in an IF of 180 MHz. A bandpass filter, 30 MHz wide, is used to select the lower sideband and provide image rejection to the upper sideband. A 42 dB gain amplifier follows the bandpass filter and provides the output from the receiver. This output is fed to the IF processing module.

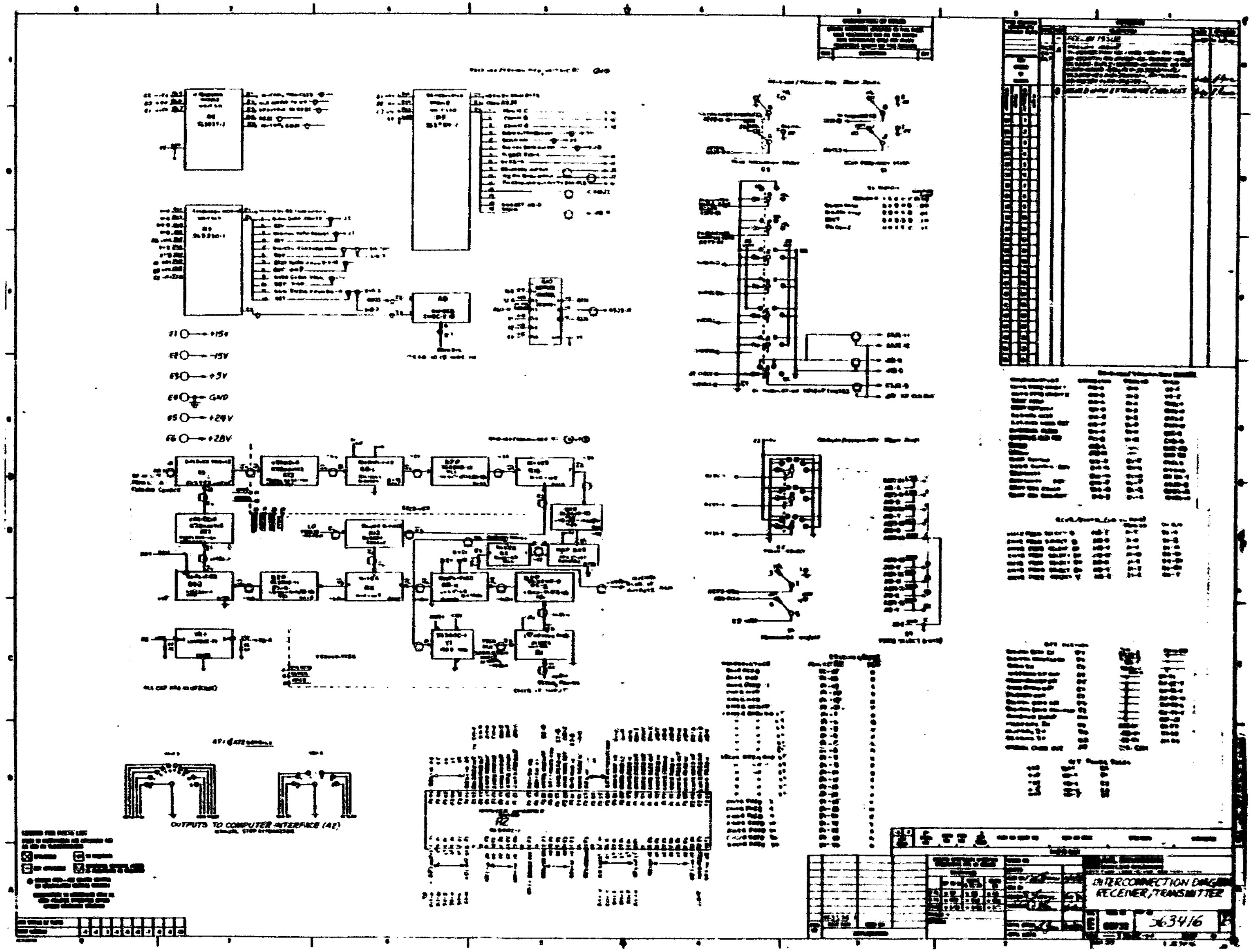


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Figure 3-17 Receiver/Transmitter Drawer Drawing No. 563416

The received signal is either BPSK data or NBFM voice.

The digital data received is in BPSK format with the carrier supressed. The incoming signal is squared, filtered and divided by two in frequency. The divide-by-two output is then a replica of the transmitted carrier and feeds the Demodulator Module and the Doppler Control Module.

The Doppler Control Module functions by sweeping the phase lock loop's VCO until the received signal is within the 50 kHz filter bandwidth. The sweep is then stopped and rapid phase locking occurs. Unambiguous signal acquisition is achieved by presetting the sweep direction.

For NBFM operation, the Doppler Loop is converted to an AFC (automatic frequency control) loop. The error sensing is accomplished using the limiter-discriminator located in the Demodulator Module. A low-pass filter is used to reduce the loop bandwidth below the lowest voice frequency component (50 Hz) to prevent the loop from following the modulation. The output of the discriminator's low-pass filter controls the VCO to maintain the IF signal centered around the discriminator, which is crystal controlled at 10.15 MHz. Thus, the VCO continuously tracks any Doppler shift present.

The Demodulator Module contains an FM discriminator for the detection of FM signals. The discriminator peak-to-peak separation is at least 40 kHz. The resulting output is sufficient to drive an audio amplifier directly. In addition to the capability of detecting analog signals, the Demodulator Module contains a digital detector for BPSK signals. If the BPSK data is to be used for an error rate test it is fed to a voice decoder for conversion back to an analog signal.

The function of the Combiner-Modulator is to accept base band input signals either in analog or digital form and suitably modulate them on a 10.15 MHz carrier for inputting to the transmitter module. When analog transmission is selected, the audio voice input is amplified and fed to the frequency modulator unit. When digital information is to be transmitted, a choice of three sources is available to the operator. One source is encoded voice which has been digitized for transmission in delta modulation form. The second source of digital data is from external inputs. The third source is from the internal Bit Error Rate Tester (BERT) when an error rate measurement is desired.

The transmitter takes an IF input signal at 10.15 MHz from the modulator, shapes the passband, upconverts the result to any of 42 doppler simulated frequencies spaced at 3.125 kHz intervals. The transmitter output power level is +23 dBm. Passband shaping is accomplished with a 2.5 MHz bandwidth filter.

The first LO, obtained from the frequency source, can vary from 89.4 MHz ±65 kHz in 3.125 kHz steps, depending upon the simulated Doppler shift. Front panel thumbwheel switches are utilized to select the simulated Doppler frequency. The corresponding IF filter is centered at 79.25 MHz and is wide enough to accommodate all frequencies. The second conversion, employing the same 1725.5 MHz LO as in the receiver, accepts the 79.25 MHz signal and outputs the selected transmitter frequency.

3.2.1.2 Control Drawer

Interconnection Diagram - 563415 Figure 3-18

The Control Drawer generates the required RF scenario signals.

The Control Drawer's 115V AC input (~5 amp) is impressed on the power supply modules. The 15V, -15V, 28V and 5V outputs are distributed throughout the entire User Terminal Simulator.

The Control Drawer outputs to the Receiver/Transmitter Drawer are comprised of 6 primary generated signals; 10.15 MHz at a power level of +5 dBm, 1725.5 MHz at a power level of +9 dBm, 2.03 MHz TTL level code signals, the 89.4 MHz 1st upconverter L.O. signal at a power level of +7 dBm, and the synch signals from BERT. The sixth signal is a pseudorandom TTL signal interfacing with the Bit Error Rate Test Unit (BERT). This signal can be varied over the range of 1, 2, 4, 8, 16 or 32 KB/S.

The Control Drawer is comprised of four (4) power supplies; ±15V, 28V and 5V; a Bit Error Rate Tester (BERT), the Frequency Source and the Bit Rate/Code Generator.

The DC outputs of the supplies are used for both the Control Drawer and the Receiver/Transmitter Drawer.

The BERT is a solid state assembly that is capable of detecting and counting errors up to 999 before indicating an overflow.

Transmit and receive data are monitored at the front panel. The front panel TTL interface connector interfaces with the Bit Rate/Code Generator Wire Wrap board which interfaces with the computer buffers and line drivers.

3-50

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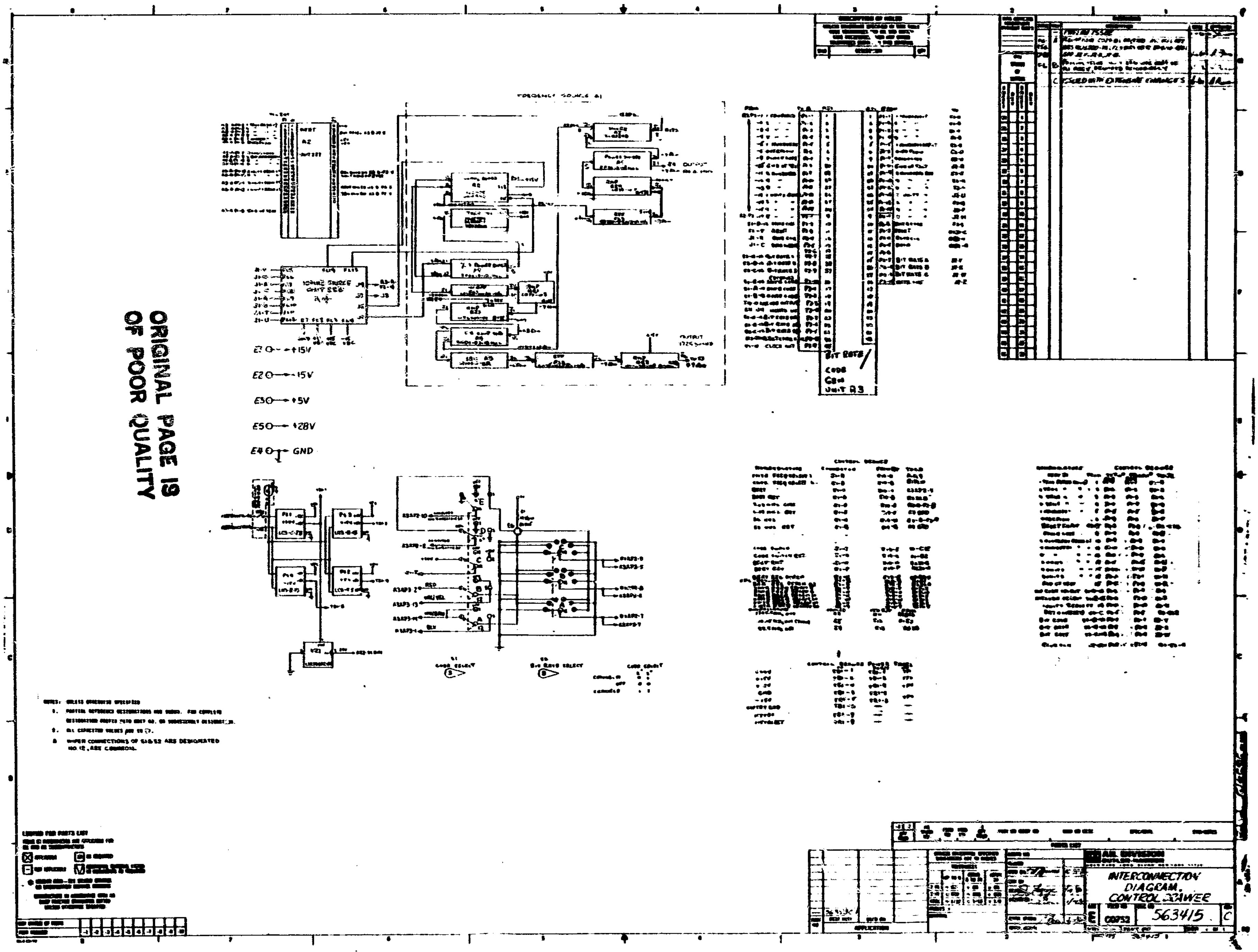


Figure 3-18 Control Drawer Drawing No. 563415

The Frequency Source generates the 1725.5 MHz signal which is distributed as the L.O. to the mixers in the receiver and transmitter. It also outputs the 10.15 MHz TCXO signal to the code generator and the modulator combiner module in the receiver. An 89.4 MHz LO generated in a phase locked loop and interfaces with the transmitter.

The Bit Rate/Code Generator provides the TTL clocks (1, 2, 4, 8, 16, 32 KBS) for the BERT and the 32 kHz signal for the delta modulator.

The Code Generator provides two 2.03 MHz codes which feed the combiner/modulator where they are added in quadrature.

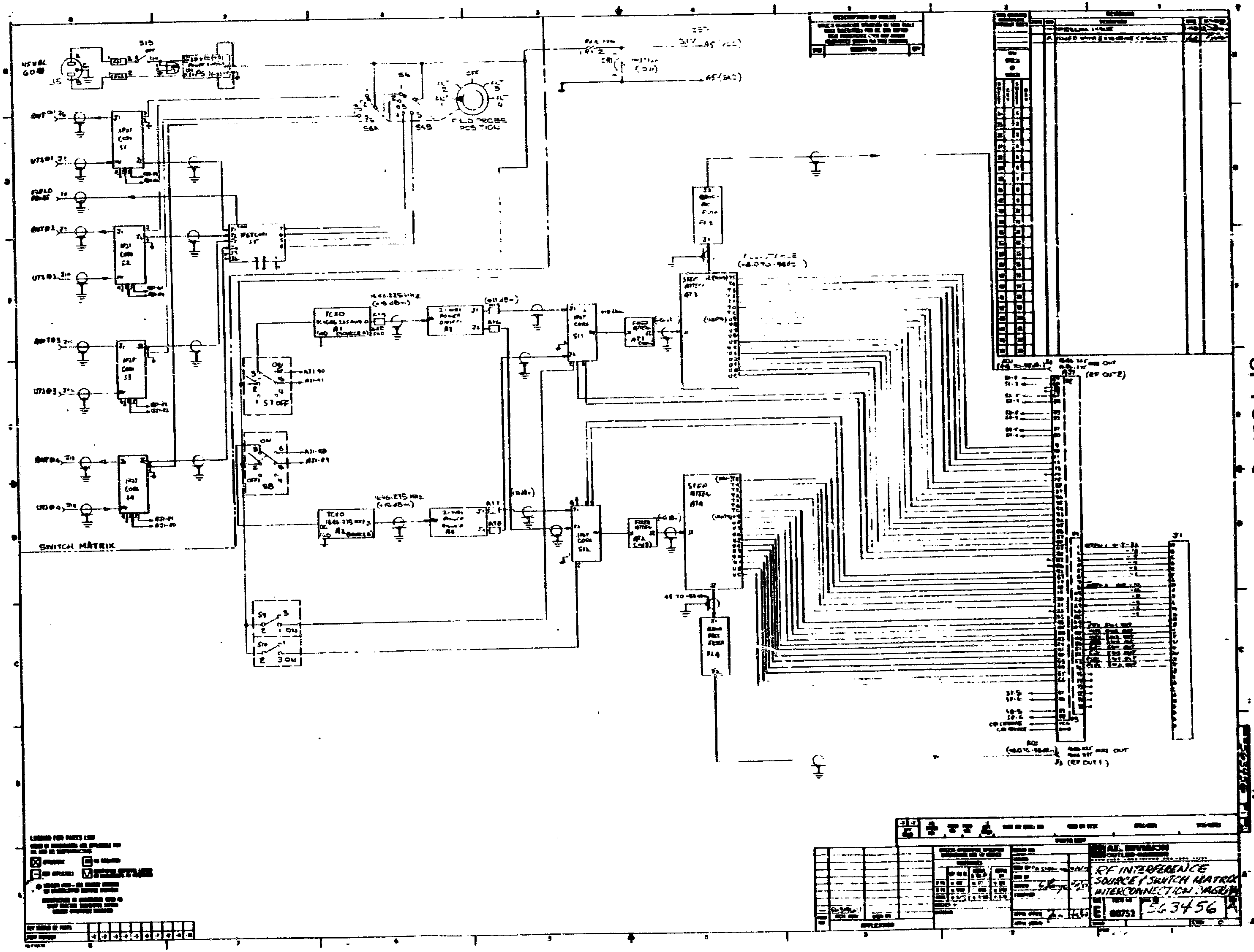
3.2.1.3 RF Interference Source/Switch Matrix

Interconnecting Diagram - 563456 Figure 3-19

The RF Interference Source/Switch Matrix is housed in a single drawer of the RF Scenario Subsystem and consists of RF sources, multiple switches and an interface board assembly. An integral power supply provides the DC power for this drawer.

This drawer used in conjunction with the other subsystems of the STE, is used to evaluate the performance of the AMPA experimental model. Two independently controlled sources provide for simulation of interference signals. Multiple switches are included for connecting each of the four (4) User Terminal Simulators (representing desired users) to the RF Field Probe Antenna. An interface board provides compatibility between signal outputs and the system computer.

3-52



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RF Interference Source/Switch Matrix Drawing

Referring to the RF Interference Source and Switch Matrix Interconnection Diagram (Figure 3 - 19), it is seen that the stimulus section of the RF interference source consists of two independently controlled temperature compensated crystal oscillators providing simulation of interference signals. One oscillator is at 1646.225 MHz (Source A) and the other at 1646.275 MHz (Source B). These oscillators provide a +15 dBm output with stability to 3 ppm at room temperature. These oscillator outputs are each fed to two (2) two-way power dividers and then routed to two (2) single pole double throw coaxial switches. These switches are DC power activated and are controlled by two front panel toggle switches. Depending upon switch selection, both sources can appear at the dual RF Output Interface, or either output can appear at the dual RF Output Interface. Switch indicators are included with these switches to provide a position indication for the system computer. Signal level control is provided by utilizing manual step attenuators in each signal path. Each attenuator is variable to 59 dB in 1 dB steps and is adjusted by a dual drum front panel mounted knob. Linearity of the attenuator is better than +0.6 dB and the insertion loss is under 0.5 dB. Provisions have been made to include an indicator switch with each attenuator. A single pole rotary switch is ganged mechanically with each attenuator drum to provide a closure for indicating drum position (value of attenuation). The switch outputs are connected to the interface connector and routed to the system computer.

Prior to their routing to the RF Output interfaces, the source signals pass through 100 MHz wide bandpass filters to further reduce any possible harmonics or subharmonics generated in the crystal oscillators. All RF cables are semi-rigid to reduce line losses.

The switch matrix section of this assembly provides connections between the Field Probe and each of the four (4) User Terminal Simulators (UTS). When each of the UTS are not switched to the Field Probe, they are connected to their respective User Terminal Antennas.

Control of all the switching is accomplished by using a front panel mounted switch which directs the DC control level to the designated switch combinations. The actual RF switching is achieved with four (4) single pole double throw coaxial switches and one (1) single pole four throw coaxial switch Switch indicators are included to provide a position indication for the system computer.

An integral power supply provides the DC power for this drawer. The supply furnishes 28 volts at 2.0 amperes.

3.2.1.4 Data Processor

The data processor is located in the RF scenario system. The data processor's function is to provide a signal conditioning interface for analog, digital and audio signals between the module subsystem, user terminal simulators and test operator.

Connectors and jacks are provided on the front panel to provide the following functions for the four user terminal simulators.

Wide band and narrow band IF output monitor points
FM output monitor points
Delta modulation monitor points
Inject external FM to user terminal simulators

The module subsystem monitor points provided at the data processor front panel consist of the Beam A and Beam B IF outputs along with demodulated FM outputs. Connections are provided for external modulation to the module subsystem for the transmit mode.

The data processor provides a central location where system signal inputs and outputs are evaluated by a test operator. The data processor contains audio amplifiers, volume controls and speakers to assess demodulated voice quality.

Jacks are provided where microphones or other test equipment can be attached so as to modulated the transmitted carrier (user terminal simulators and/or experimental model transmitter).

3.2.2 RF Manual Test Rack

Figure 3-20

The RF Manual Test Rack provides the capability to test the AMPA array subsystem separate from the module subsystem. It is used in conjunction with the STE but without requiring the system computer for subsystem operation.

This rack was used during preliminary testing of the subsystem to evaluate the beam forming and pointing capability of the array. It was used as an interface between the array subsystem and antenna pattern recording test equipment.

The RF Manual Test Rack is a stand alone console capable of operating independently from the STE. The console is a desk top rack 22 inches wide x 36 9/16 inches high x 25 inches deep. The RF Manual Test Rack contains the following four (4) subassemblies:

- Power Supply
- Control Monitor
- Receiver Test
- Transmitter Test

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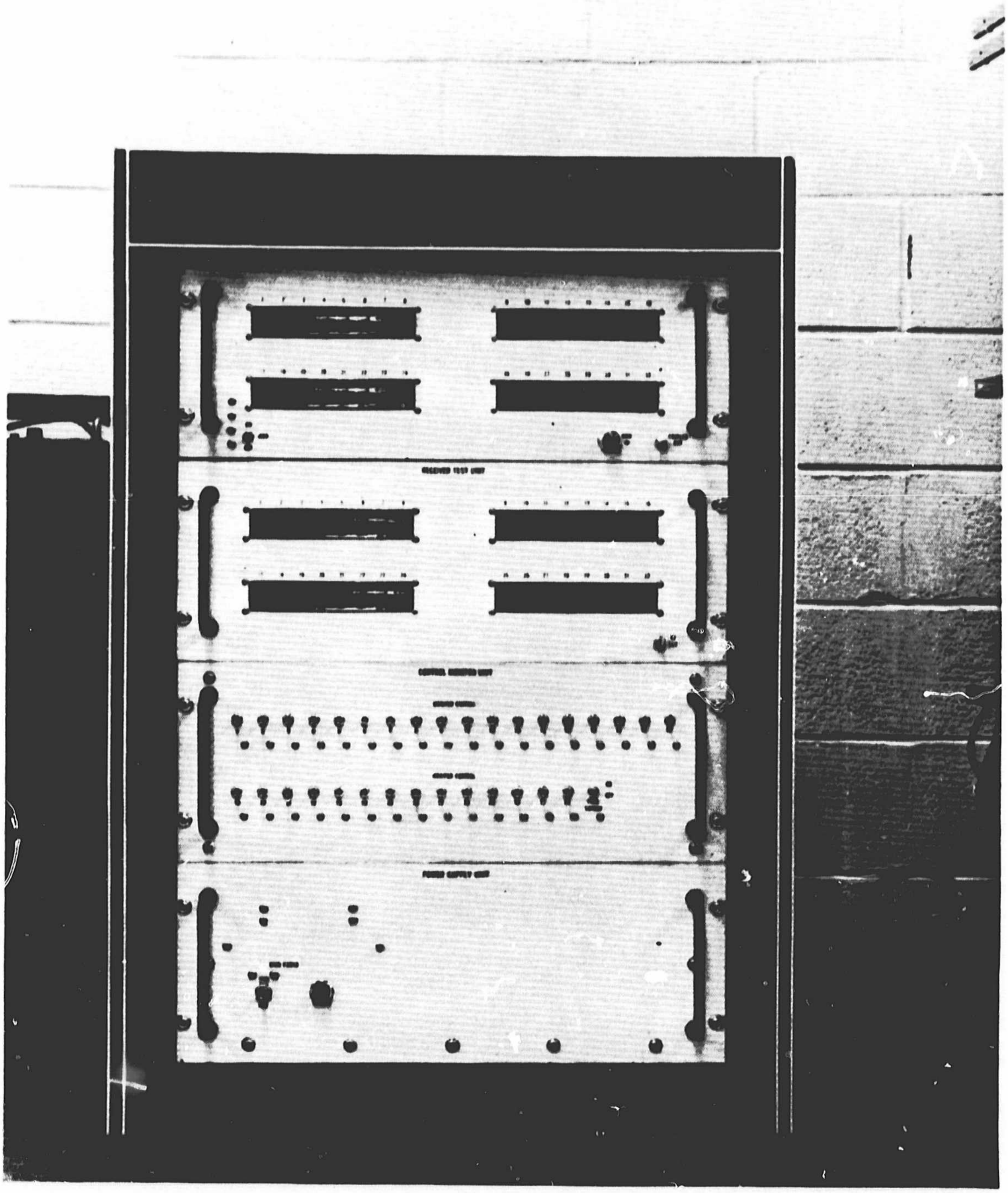


Figure 3-20 RF Manual Test Rack

A diagram illustrating the input/output electrical interface between the four (4) subassemblies that comprise the Manual RF Test Rack is shown in Figure 3-21. With reference to the individual subassembly interconnection diagrams and assembly drawings, the following description presents the operation of these subassemblies.

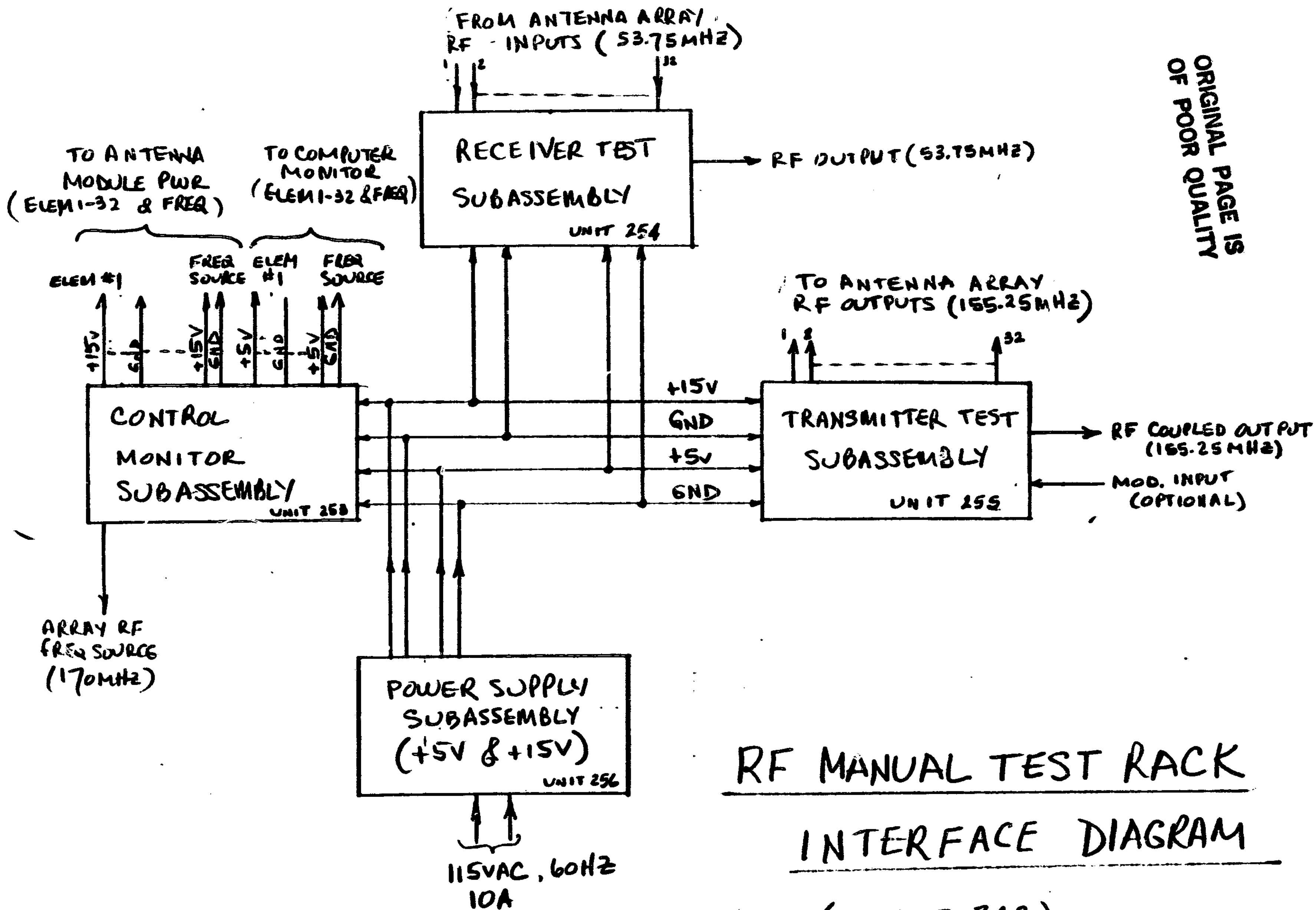
3.2.2.1 <u>Power Supply Subassembly</u>

Interconnecting Diagram - 563449 Figure 3-22

The Power Supply Subassembly is housed at the bottom of the console. The function of this unit is to provide the necessary D.C. power for the entire Manual Test Rack as well as the array subsystem.

AC Power is brought into this unit through a rear mounted detachable AC cable. The AC power is controlled by a front panel toggle switch which also performs as an electromagnetic circuit breaker, providing circuit protection should the AC current exceed 12 amperes. An indicator lamp is furnished to indicate main power status. The DC supplies contained within this subassembly are purchased regulated supplies with low output ripple. One supply furnishes 15 volts at 28 amperes, while the other furnishes 5 volts at 16 amperes, including fixed over-voltage protection. These DC supplies furnish the DC power for the entire Manual Test Rack and the array subsystem, since total power requirements are 18 amperes at 15 volts and 13 amperes at 5 volts.

An interconnection diagram for this unit is shown in Figure 3-22. All interconnecting wire is heavy gauge #16, and safety cover protectors are placed over all interior and exterior exposed terminal boards. All DC power



RF MANUAL TEST RACK INTERFACE DIAGRAM

(UNIT 242)

Figure 3-21

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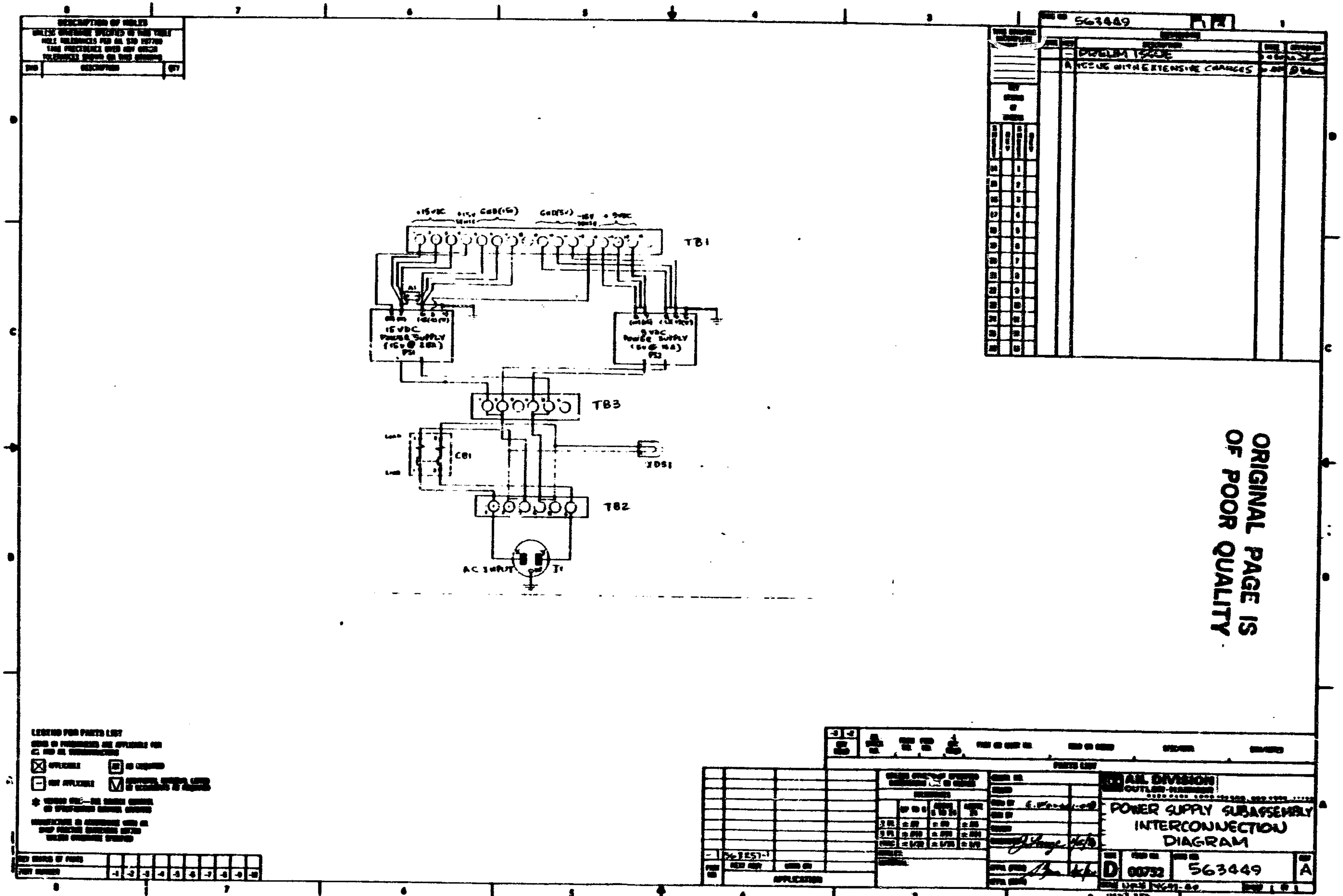


Figure 3-22 Power Supply Subassembly Drawing No. 563449

3-59

furnished to the remaining subassemblies is available in a sixteen (16) lug terminal board mounted at the rear of this unit.

The only electrical interconnections between the four (4) subassemblies of the Manual Test Rack are for DC power. The interconnection diagram of the Manual Test Rack Assembly (Drawing #563464) shows this dependence to the Power Supply Subassembly. The DC input connections to all subassemblies is furnished with the same type sixteen (16) lug terminal boards. Heavy duty #14 gauge wire is used to carry this DC power from the Power Supply Subassembly to the other units.

3.2.2.2 Control Monitor Subassembly

Interconnecting Diagram - 563461 Figure 3-23

The Control Monitor Subassembly performs several functions. These functions can be seen in the interconnection diagram for this unit and are described in detail below.

A temperature compensated crystal oscillator at a frequency of 170 MHz provides a stable reference signal to drive the array subsystem frequency source. The oscillator, at a nominal frequency of 170 MHz, provides a +20 dBm output with stability to 3 ppm at room temperature. This RF output is then padded down and fed to a 10 MHz wide bandpass filter, to further reduce any possible harmonics or subharmonics generated by the crystal oscillator. An output of +13 dBm is available at the rear of this unit for connection to the subsystem.

DC power of +15 volts for the array subsystem is controlled in this unit by thirty-three (33) front panel subminiature toggle switches. As each antenna module is powered on, a +5 volt level is also supplied to the interface for transmission to the system computer to monitor the antenna module DC power status. Both the +15 volt and +5 volt output interface connectors are rear

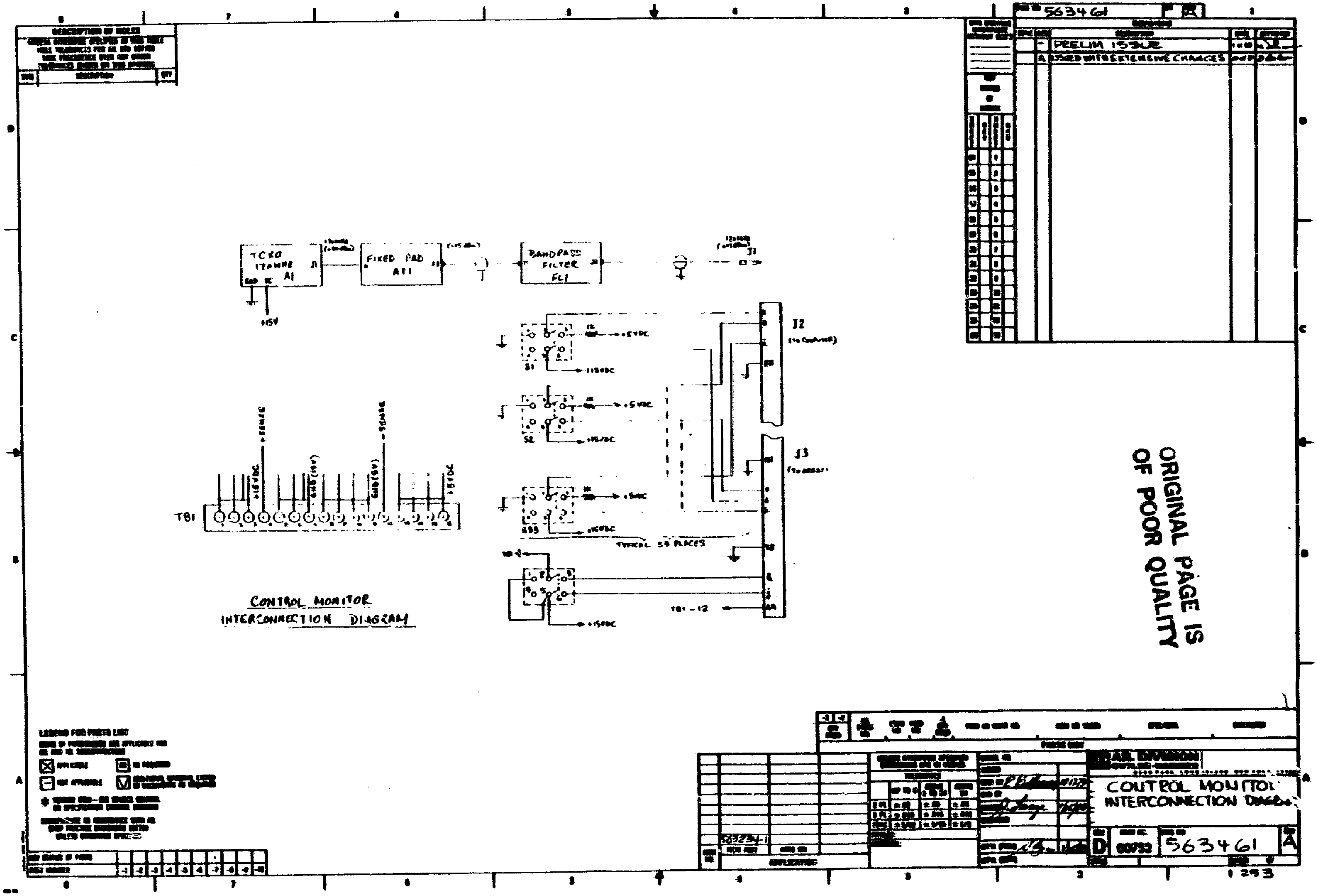


Figure 3-23 Control Monitor Subassembly Drawing No. 563461

3-61

mounted 55 pin socket, miniature circular bayonet-lock (pygmy) connectors.

3.2.2.3 Receiver Test Subassembly

Interconnecting Diagram - 563447 Figure 3-24

The Receiver Test Subassembly accepts the thirty-two (32) signals from the array subsystem, furnishes independent phase weights, and combines these signals into a single composite output signal.

Referring to the interconnection diagram of the Receiver Test Subassembly, it is seen that this unit receives the RF inputs at a nominal frequency of 53.75 MHz over a dynamic range of -107 to -52 dBm. These inputs are connected directly to the input ports of thirty-two (32) independently controlled digital phase shifters mounted at the rear of this assembly.

The phase shifters are controlled directly from four (4) bit TTL logic levels. Phase is shifted to binary increments from the LSB of 22.5 degrees to the MSB of 337.5 degrees.

These digital phase shifters are manufactured by Merrimac Industries. They are designed to be controlled directly from four (4) bit TTL logic levels. Phase is shifted in binary increments from the LSB of 22.5 degrees to the MSB of 337.5 degrees.

A computer study indicated that this 22.5 degree phase resolution was adequate to satisfy the requirements of the Manual Test Rack when testing the array subsystem. Using these four (4) bit phase shifters to control beam pointing, at five (5) assumed spatial boresights, the array gain was found to be degraded less than 0.1 dB from the optimum gain obtained with perfect (infinite resolution) phase shifters.

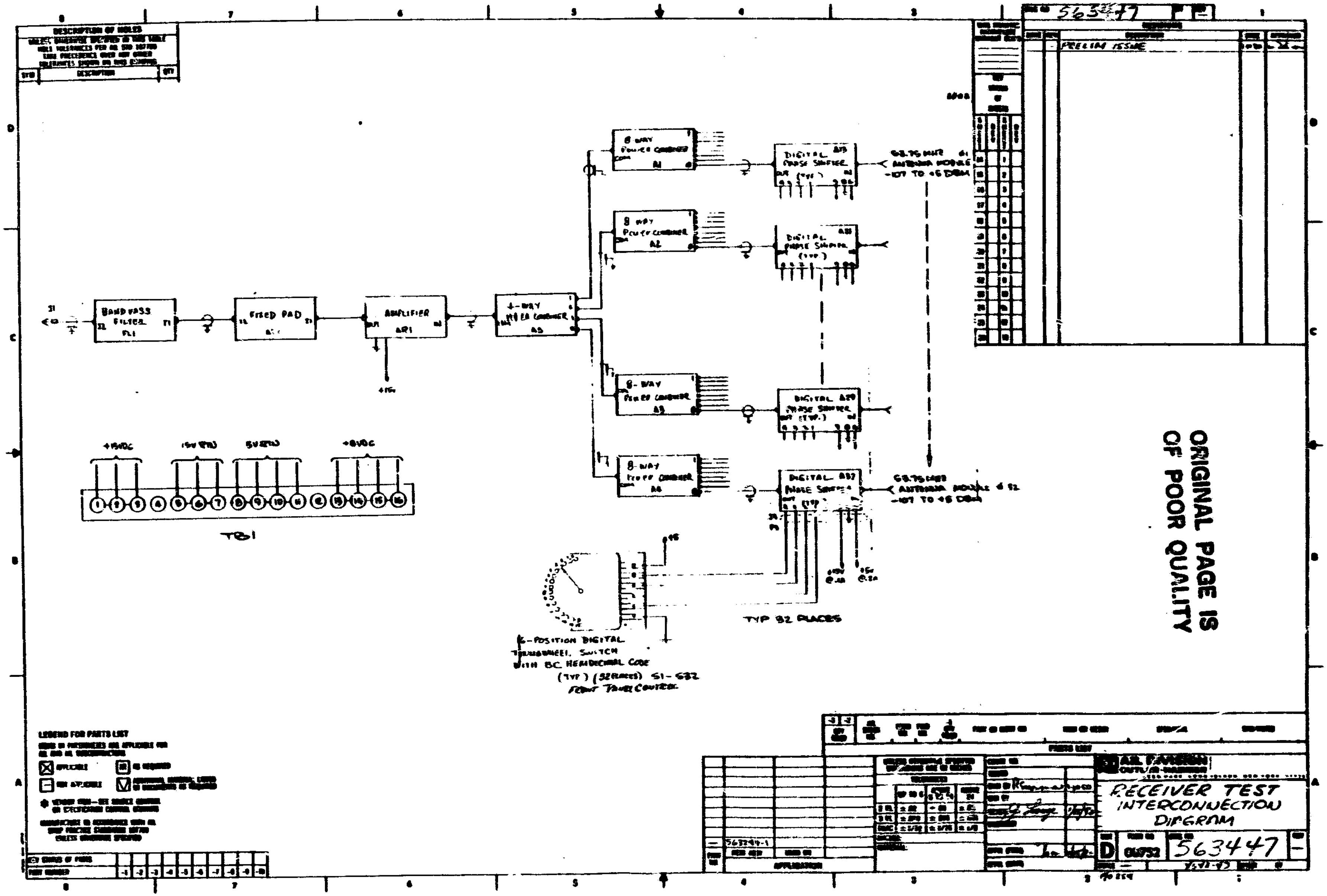


Figure 3-24 Receiver Test Subassembly Drawing No. 563447

Digital control of the four (4) bit TTL logic is accomplished by the use of thirty-two (32) front panel mounted thumbwheel switches arranged in four (4) groups on the front panel of the subassembly. Every switch corresponding to its respective antenna element is clearly marked on the panel.

Each of thirty-two (32) thumbwheel switches controls its own digital phase shifter by utilizing a binary coded hexidecimal output code in its sixteen (16) position switching operation. Each switch position changes the phase shift by another 22.5 degrees ensuring that the phase can be varied discretely over a 360 degree range in increments of 22.5 degrees. These thirty-two (32) switches are manually adjusted to control their respective digital phase shifters so that the phase shifted input signals combine at the summing output port of the receiver test subassembly.

Signal combining is accomplished by directing the thirty-two (32) outputs of the phase shifters into four (4) eight-way power combiners and then feeding the single port outputs of these eight-way power combiners into a single four-way power combiner. A total gain of 15 dB occurs due to this passive power combining. A cascadable amplifier with a typical gain of 54 dB further amplifies this output to the required interface levels. The composite signal is then applied to a 4 MHz wide bandpass filter and finally directed to a single front panel output connector. Sufficient gain is provided to ensure a -55 to +0 dBm output level.

3.2.2.4 Transmitter Test Subassembly

Interconnecting Diagram - 563446 Figure 3-25

The Transmitter Test Subassembly supplies thirty-two (32) adjustable phase weighted signals to the array subsystem.

C - 2

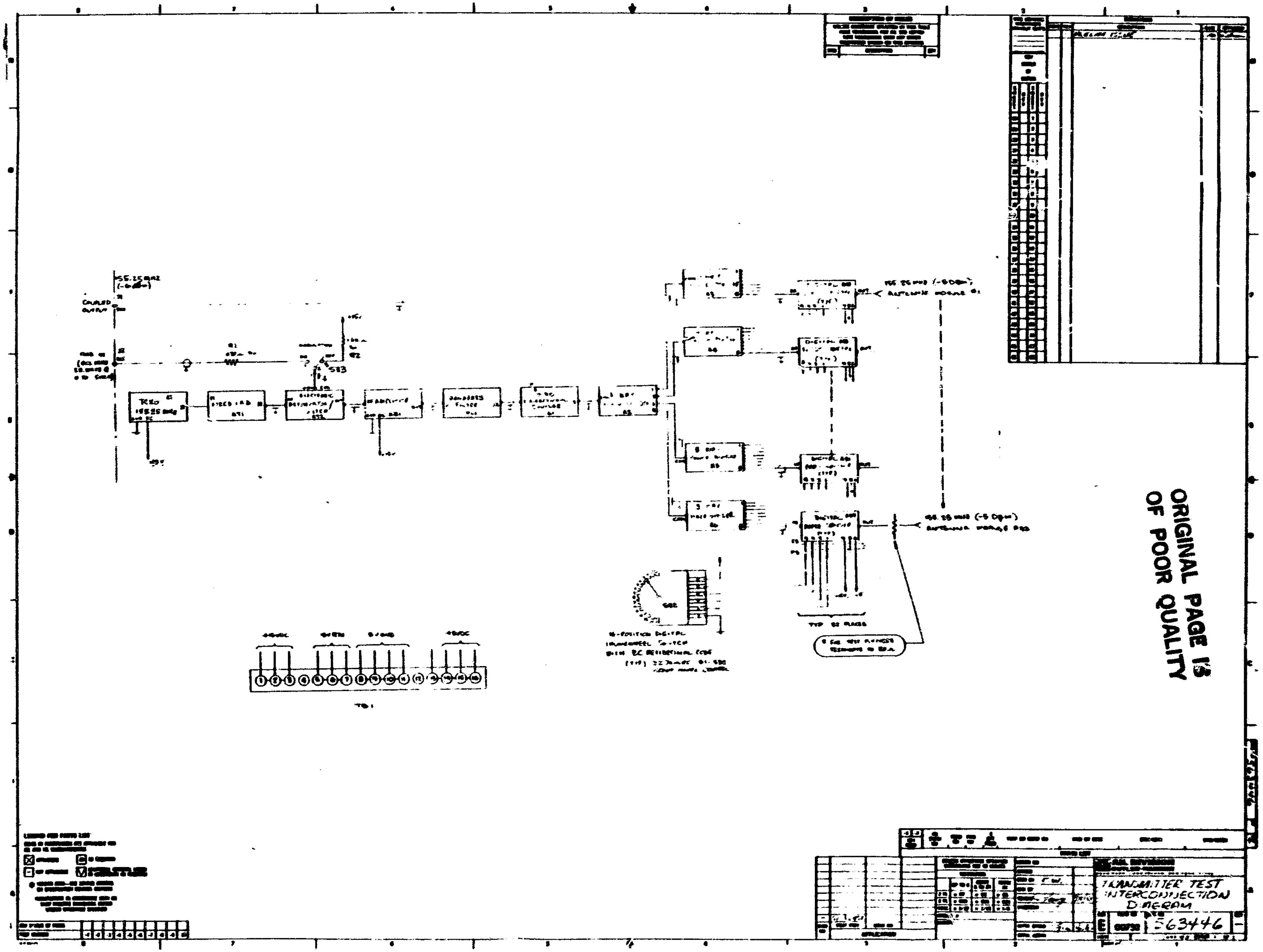


Figure 3-25 Transmitter Test Subassembly Drawing No. 563447

Referring to the interconnection diagram of the Transmitter Test Subassembly, it is seen that the frequency source utilized is a temperature compensated crystal oscillator at a frequency of 155.25 MHz. This oscillator output is then fed to an electronic attenuator/switch. Due to the requirements for antenna pattern recording equipment, external modulation can be introduced into the subassembly at this point. When modulation is not required, the attenuator is biased for minimum attenuation and the input oscillator signal is directed to a cascadable amplifier with a nominal gain of 13 dB. This signal is then applied to a 10 MHz wide bandpass filter and fed into a 20 dB directional coupler. The coupled port is routed to a front panel connector for test purposes prior to signal splitting. The direct path is applied to a four-way power divider. Each of the four (4) outputs from this divider are directed to four (4) eight-way power dividers. The outputs of these power dividers consist of thirty-two (32) coherent signals. These signals are then applied to thirty-two (32) independently controlled manual phase shifters mounted at the rear of this assembly. The specifications of these shifters are identical to those utilized in the receiver test subassembly, except that the center frequency in this subassembly is 155.25 MHz. Control of the digital phase shifters is accomplished by employing thirty-two (32) front panel mounted thumbwheel switches, each with sixteen (16) positions and binary coded hexidecimal output code. The thirty-two (32) switches are manually adjusted to control their respective digital phase shifters so that thirty-two (32) independently phase shifted signals appear at the output interface ports. Sufficient gain is provided to ensure a -5 dBm output level at each output connector.

3.2.3 STE Mgt. System

The STE Mgt. System's function is to operate and control the AMPA Experimental Model during the system testing phase. The heart of the STE Mgt. System is a central computer by which a test operator controls the Experimental Model through computer driven interfaces. The STE Mgt. System is made up of the following computer and peripheral equipment:

Central Computer

Hard Copier

CRT/Keyboard

Tape Recorder

Mass Storage

The central computer is a PDP11/34. A test operator controls the system operation through the PDP11/34. The system data interface to the computer is made through DR-11C interface cards. System testing activities are through keyboard entry commands or through test programs running on the computer.

Each of the User Terminal Simulators and the interference sources have many switch selectable functions such as frequency, power, modulation, etc. The configuration of these units is output to the computer for inclusion to the tape recorder. Additional output data sent to the computer consists of the on/off status of the antenna modules and output data from each of the BERT units (User Terminal Simulator and Modem).

The computer provides an output interface to the module subsystem (Dedicated Experiment Processor and Modem) for configuring the Experimental Model. The weights from the Receiver Processor and Transmitter Processor are included as output data words which interface with the computer and mass storage unit for future analysis.

3.2.3.1 Central Computer

The STE utilizes a PDP11/34 computer to control the system operation as well as to perform the non-adaptive algorithms. The memory used is MOS with 128K 16 bit words. In addition, a 2K cache memory is also available. Cache memory reduces the cycle time for frequently used main memory addresses thus enabling the quicker execution of programs. A floating point processor is also included with the PDP11/34 to execute floating point arithmetic operations. Other options that are included are the

LP11-VA line printer	-	to enable hard copy of the programs during debugging and testing.
KW11-P	-	a programmable clock to enable control of when certain programs should be run.
QT100-AP	-	Fortran IV plus compiler software RSX11M Operating System (Multitask Operating System)
PC-11	-	Reader/Punch to enable programs to be read in on paper tapes. AIL has a DEC 20 system that can also be used to debug some of the programs. These programs can be loaded from and to the DEC 20 system and the PDP11/34.
VT-100		CRT/Keyboard Controller

3.2.3.2 Tape Recorder

The PDP11/34 utilizes the TJE16 magnetic tape 9 track storage system to record and archive the data. It uses standard recording formats with densities of 1600 and 800 bits per inch selectable under program control. Read and write

are performed at 45 inches/second, giving a maximum 72,000 character/second transfer rate which can easily handle the expected AMPA data rates.

3.2.3.3 Mass Storage

Mass storage is provided for the PDP11/34 by the use of an RL11 and RL01 10 MB disk system. The disk provides 10M bites of data storage. Average access time including head alignment is less than 68 milliseconds thus providing 512K bites per second transfer rate.

3.2.3.4 CRT/Keyboard Unit

In addition to the PDP11/34 CRT/Keyboard, a graphics terminal to plot footprints is included in the STE management system. This graphics terminal is a Tektronix 4014-1 Terminal. The terminal provides a display area of 15" x 11" on a 19" diagonal screen. It employs a storage tube with high resolution. Tektronix also supplies the PLOT 10 software package which is directly compatible with the PDP11/34.

3.2.3.5 Hard Copier

A companion unit to the Graphics Terminal is the Tektronix Hard Copier 4631 which is also included in the STE. The 4631 provides permanent dry copies of any information on the screen.

4.0 Software/Firmware Implementation

4.1 Introduction

The software is resident in the PDP 11/34 computer which is part of the AMPA Special Test Equipment (STE). The software exercises the interfaces and executes test functions to checkout the AMPA Experimental Model. The software also drives the AMPA Experimental Model in its multiple configurations providing various beam pointing and beam forming combinations. It allows displays of beam footprints to evaluate the Experimental Model performance for various communication and pointing modes. AMPA Status data is also outputted.

The software also facilitates the tape recording of all experimental data. Post test software extracts selective data from tape for analysis of the various tests that have been run. Configuration commands and intermediate test data are archived for outputting to a printer or other output devices to verify the test configurations.

Firmware is resident in the Dedicated Experiment Processor. The Dedicated Experimental Processor (DEP) is the special purpose device which 1) acts as interface between the PDP-11 controller of the AMPA experiment and its RF and analog elements and 2) performs the high speed adaptations and correlations necessary for the AMPA to perform its real time function. The DEP works from a stored microprogram contained in the twelve 8-bit wide PROMS, giving a 96-bit control word. Program preparation is facilitated by a language and assembler (SPAL) which recognizes fixed mnemonics for operations and allows programmer-defined labels for program data and branch locations.

4.2 Software Implementation

The AMPA Experimental Model is controlled by a single PDP 11/34 computer (Figure 4-1). The system software package consists of eleven application tasks, the RSX-11M Operating System plus other various offline functions.

The software performs its various functions based on the execution of configuration commands that will have been loaded into a configuration command buffer prior to starting a test. Initially the AMPA Experimental Model will be manually calibrated and subsequently the calibration algorithm will permit these calibration constants to be refined.

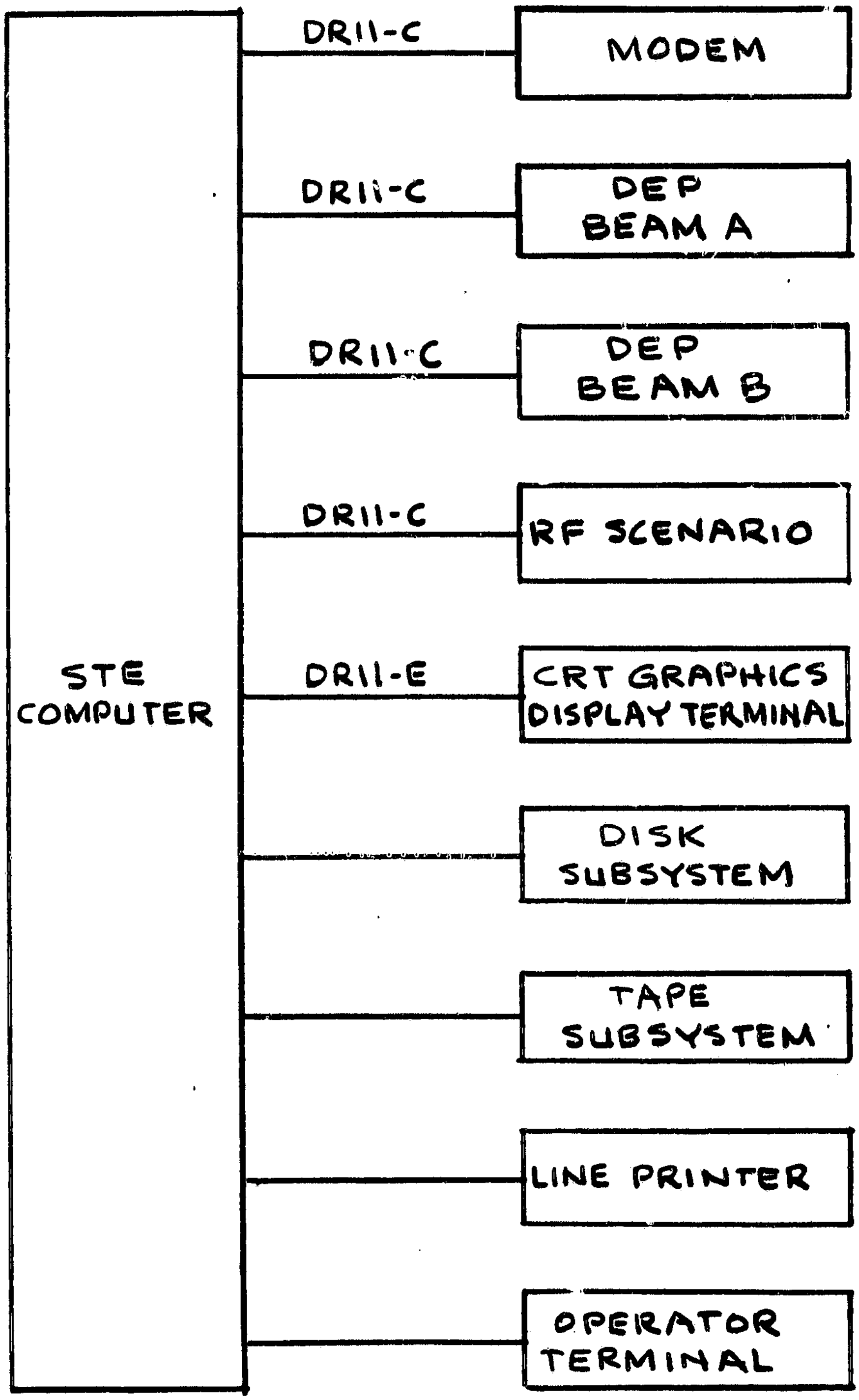
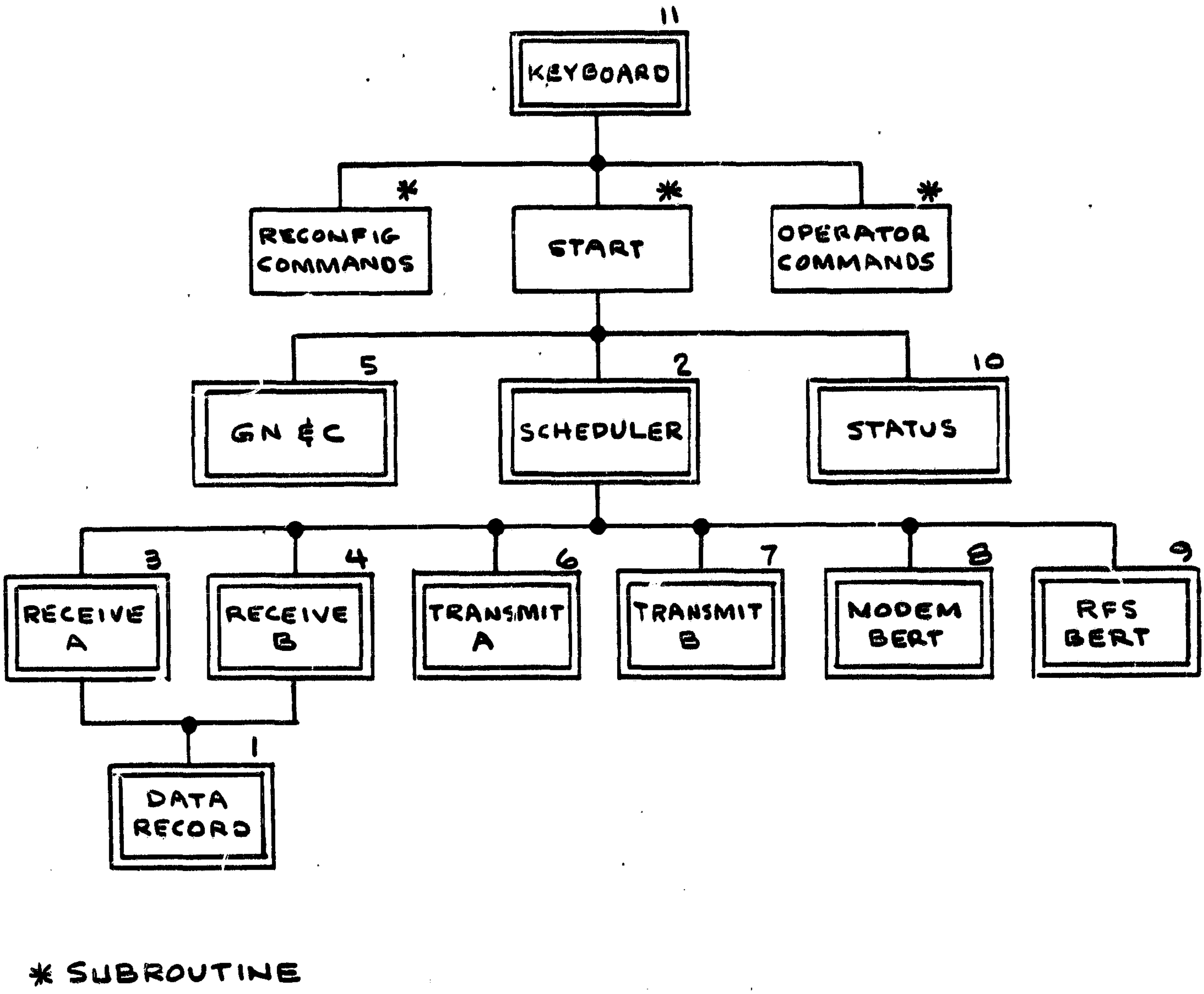


FIG 4-1 AMPA COMMUNICATIONS SYSTEM SINGLE COMPUTER CONFIGURATION

The PDP 11/34 software is driven by data and events (CRT operator inputs). Its major function is to respond to interrupts caused from external sources and to service such interrupts in a prioritized fashion. There are four (4) major interfaces: A) AMPA Experimental Model via DEP Beam A&B and Modem, B) RF scenario status interface, C) operator terminal interface where there is operator interaction and D) CRT graphic display terminal. To service these interfaces the STE software consists of the following tasks that are listed in order of priority.

1. Record
2. Scheduler
3. Receiver A
4. Receiver B
5. GN&C
6. Transmitter A
7. Transmitter B
8. Modem BERT
9. RFS BERT
10. Status
11. Keyboard

Figure 4-2 depicts the software hierarchy.



REV. A

FIGURE 4-2 SOFTWARE TASK HIERARCHY

4.2.1 Keyboard Task

Two major functions are performed by this task, the initial setup contact with the operator and the real time command interface with the test operator. The first of these is performed by initializer module which is called by the Keyboard task.

Initializer Module

The Initializer obtains from the operator, the parameters of the test to be run, the conditions for the test and all parameters necessary to generate the header record of the test documentation tape. It also initializes the software control parameters, indices, pointers, event flags, etc. It also initializes data sets where required and places disc stored data such as calibration constants in the required locations.

Keyboard Message Interpreter

The purpose of the Keyboard Interpreter Module is to interpret messages that are input by an operator who is controlling the AMPA experiment. Upon identifying the message type this module will initiate calls to pertinent subroutines that will initiate or modify an experimental test. The execution of the START subroutine activates the scheduler task. This permits execution of the stored commands and automatic system operation.

4.2.2 Scheduler Task

The function of the scheduler is to manage the stored command buffer to execute the commands at the proper time. It also schedules the execution of the commands in coordination with the performance of the transmit and receive tasks. The task uses the operating system event flag and timing resources to accomplish these functions. The scheduler calls a command interpreter subroutine to execute the contents of the command buffer.

Command Interpreter

The purpose of the Configuration Command Interpreter is to interpret the various commands that are installed in the command buffer and take the necessary actions that are requested by the commands. The buffer commands can be prestored on disc or inserted manually from the keyboard. These commands are interpreted in the order in which they are installed in the command buffer. The commands allow configuring the experiment and STE, and then initiating the software tasks to run the experiment to obtain specific data. A manual override capability allows operator intervention before or during any experimental run. When a command(s) has been input manually it will have the highest priority of any command in the buffer when execution of the commands is restarted. Thus, the operator can control any phase of an experimental run. The operator can reconfigure the DEP modem and/or RF interface(s) as well as the modes of the receiver/transmitter task(s).

4.2.3 Data Collection and Recording Task

This task will control the collection of weight data from the receive A and B beam interfaces in the track mode. These data are output to the tape recorder for off line analysis. An alternating buffer scheme is used for each beam. When one of the buffers is filled, it will be output to tape while the second buffer is accepting new data. The task is started by the initializer module and responds to event flags set by the receiver tasks when track mode is entered. During tracking the task responds to outputs from the STAR I/O Driver.

4.2.4 Receiver Task

During the AMPA experiment, the receiver tasks control the receivers for Beam A and Beam B via DEP Beam A & Beam B interfaces, respectively. The task becomes active when the supervisor processes a configuration command requiring receiver activation and then issues a receiver task activation to the operating system.

The task consists of the following four modules: 1) Receiver Controller Module, 2) Open loop pointing module, 3) Adaptive Receive Module and 4) Receiver Calibration Collection Module.

Receiver Controller Module

This module extracts the Beam ID, frequency and pointing mode from the beam data set and then formats the control data word to send it to one of the DP interfaces. Then control is passed to the appropriate receiver modules.

Open Loop Pointing Module

This module generates a set of normalized weights which will point the beam in a command specified direction. The module accepts pointing information in the form of rotational and elevation angles with respect to the array face, and also in terms of earth latitude and longitude. The module is callable by both the receiver and transmitter tasks. Maximum update rate for pointing is 10 seconds.

Adaptive Receive Module

The Adaptive Receive Module supports acquisition, geolocation, coarse and fine modes. In the acquisition mode, each cell is scanned until receiver lock is indicated. Then the system is put into track mode.

In geolocation mode cells along an isodoppler contour are scanned, then the maximum signal level is found and the levels near the maximum are interpolated to determine the signal location.

The interaction between the host computer and the DEP proceeds as follows:

1. Host computer selects cell number and sends weights to the DEP when in the acquisition mode or the geolocation mode.

2. The DEP interrupts the host program and returns updated weights, lock status and signal power.

3. If the system is in the geolocation mode the program returns to step one for all the cells on an isodoppler contour. Then, upon completion of all the cells, the program executes the interpolation algorithm.

4. If the system is in acquisition mode, the Doppler Lock Indicator is checked. If it is not set, the program will recycle.

5. When the Doppler Lock Indicator is set, the program goes into track mode via the MSIR algorithm in the DPM.

6. Once in track mode, the DEP program periodically checks the track status and collects weights for recording.

Receiver Calibration Data Collection Module

The Receiver Calibration Data Collection Module configures the receiver beam so as to make the measurements necessary to update the calibration constants. The computer commands the DEP in the acquisition and then track modes. Corelations for each element are then read. The calibration calculations are accomplished in a separate update calibration module.

4.2.5 Transmitter Tasks

During the AMPA experiment the transmitter tasks control the transmitter Beam A and Beam B in the DEP interfaces. The task becomes an active task when the supervisor task processes a configuration command and then issues a service request to the operating system to activate it.

The transmitter task consists of four modules: 1) Transmitter Controller Module, 2) Open Loop Pointing Module, 3) Transmitter Nulling Module and 4) Transmitter Calibration Collection Module.

Transmitter Controller Module

The Transmitter Controller Module outputs the control data word to the DEP and determines which module within this task should be performed.

Open Loop Pointing

See Open Loop Pointing for receiver task.

Transmitter Nulling Module

This module calls the subroutine (algorithm) that performs the transmitter nulling and returns normalized complex weights in integer form to this module.

These weights are formatted for the DEP, output to the tape recorder and output to the DEP.

Transmitter Calibration Data Collection Module

The Transmitter Calibration Data Collection Module controls the pointing and modulation of the transmitter beam in order to make measurements necessary to update the calibration constants.

4.2.6 Status Task

The status polling/display task, is the last task to be activated from a priority standpoint. It is invoked by an operator initiated display request for the RF or AMPA configuration display. This task is also run periodically for the acquisition of status data. When an error condition occurs during the checking of status, an appropriate message will appear on the CRT.

4.2.7 BERT Task

The BERT receives data from the modem BERT and/or RF Scenario BERT and outputs the data to magnetic tape, when commanded. Because the BERT task is a separately running task, BERT data can be input at high data rates, without seriously degrading the response time of the rest of the AMPA software.

4.2.8 Calibration Task

The Calibration Task uses measured data from several passes or different RF antennae stations to compute a correction to the antenna array calibration constants. The correction is computed in a least square sense from at

least five independent observations. The operator calls this task as required.

4.2.9 GNC Data & Command Generator Programs

The command operator is an operator interactive program which may be used to generate a file of commands stored on disc. The file will be executed from the command buffer during testing operations. It is also used to permit operator entry of commands in real time.

The GN&C program is a task which operates periodically in real time. Based upon orbital parameters (inputs) it generates simulated GN&C data for use by the pointing and location algorithm.

4.2.10 I/O Drivers

Three I/O Drivers were written to enable input/output communications between the host and external devices. The interface utilizes a DR11C. These are the 1) Modem, 2) DEP, and 3) RF Scenario Status. The drivers are called from their respective allocated tasks or by interrupts from the devices. Detailed operational requirements are described in the Software Summary Report. A fourth driver to interface with the graphics display is supplied as part of the operating system.

4.2.11 Post Test Processor

This program enables the retrieval of data. This off line processor enables the scanning, reading and selecting of data from tape given time as the selective parameter. The data may be output directly or used for footprint generation.

4.2.12 Footprint Module

This module is only activated when a footprint is requested by the operator and it is the most time consuming since it has numerous computations. The CPU time that it consumes increases with increased resolution. However, this program is run off line. The input request includes beam ID, resolution, contours desired, FOV and any other necessary parameters.

4.2.13 Data Base Description

Data sets are used to pass data between the main programs and subroutines. A data base was set up utilizing the following data set type:

a) Constants, i.e., PI = 3.141573
b) Search - beam angles for set of cells
c) GN&C
d) Configuration Command Buffer
e) Configuration Status
f) Beam Data Set
g) Calibration Constants
h) Calibration Collection
i) Current Calibration Matrix Data Set
j) Initial Calibration Matrix Data Set

A detailed description of each individual data set is included in the Software Summary Report.

The software is written mainly in Fortran with only certain exceptions (I/O Drivers), where assembly language will be used. All the software was developed on a PDP 11/34 computer with the RSX-11M operating system.

A typical display as provided on the test operators CRT/Keyboard unit is shown in Figure 4-3.

09-DEC-80 15:51:59

RF SCENARIO STATUS

UT$	1	2	3	4
TX	ON	ON	ON	ON
TX ATTEN	1 DB	2 DB	4 DB	8 DB
TX MOD	BPSK	DELTA	BERT	FM
CODE	OFF	A	OFF	B
RCV FREQ	LOW	HIGH	LOW	HIGH
RCV ATTEN	8 DB	4 DB	2 DB	1 DB
RCV MOD	BPSK	FM	BPSK	FM
BERT RATE	1 K	4 K	8 K	32 K

TX 1 FREQ 1646.275000 MHZ
TX 2 FREQ 1646.253125 MHZ
TX 3 FREQ 1646.225000 MHZ
TX 4 FREQ 1646.200000 MHZ

FLD PROBE UT 3

INT. SRCE	A	B
ATTEN SET	8 DB	16 DB
FREQ	HIGH	HIGH

ELEM OFF 8 14 15 16 31

00:11:

SYSTEM STATUS

BEAM ID	A	B
COM MODE	SIMP XMIT-RCV	SIMP XMIT-RCV
XMTR FREQ	LOW	LOW
XMTR POINT	DYNAMIC	DYNAMIC
XMTR SRC	EXT	EXT
XMTR MOD	FM-EXT	BPSK-EXT
XMTR RATE	FM	4 KBPS
XMTR ATTEN	0 DB	21 DB
RCVR FREQ	LOW	LOW
RCVR RATE	FM	4 KBPS
RCVR BERT	OFF	OFF
RCVR POINT	DYNAMIC	DYNAMIC
TX P EL/LAT	30.00	0.00
TX P RO/LON	-60.00	0.00
TX N EL/LAT	0.00	60.00
TX N RO/LON	0.00	0.00
RX P EL/LAT	30.00	60.00
RX P RO/LON	-60.00	0.00

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Figure 4-3. Operator Terminal Display

4.3 Firmware Implementation

The DEP Interface provides buffers for two transmitter beams and computes weights for two receiver beams. The DEP also provides controls and interfaces with the Host Processor (HP). The Transmitter Processor (TP), the Receiver Processor (RP), and the Signal Processor (SP).

The DEP can be subdivided into two units. The basic aspect of this architecture is to process Beam A and Beam B independently. Should a hardware failure occur in one beam processor, the other processor can still function without interference. The DEP contains a Digital Processing Module (DPM).

The purpose of the Digital Processing Module (DPM) is to implement the receiver beamforming algorithms. Basically, the DPM will receive correlations from the Signal Processor and then compute weights for the Receiver Processor. The DPM is capable of performing a go/no-go type of self test by executing one of the receiver algorithms. The DPM executes its functions at a 5 MHz rate.

The DEP works from a stored micro-program in 12 (8-bit wide) PROM's, thereby generating a 96 bit control word (used for program branching, looping, steering flow of data, I/O capabilities, etc.). Program preparation is facilitated by a language and assembler (SPAL) which recognizes fixed mneumonics for operations and allows defined labels for program data and branch locations.

This program, or firmware, is described in the following section. A self explanatory programmed flow chart accompanies this description. (See Figure 4-3).

On initial power turn on, constants needed for the necessary computations are generated and stored in the allocated RAM locations. The DEP remains in a "waiting" loop, searching for an interrupt (CSR1) from the Host Computer. After an interrupt has been recognized, the data which consists of the control word, data (weights and assigned addresses - 64) and two trailer words doppler, threshold code) is transferred into RAM. The Mode selection (transmitter point, receiver point, acquisition, coarse geolocation, fine geo/calibration, track or self test) is determined by the three least significant bits in the control word data format.

DEP FIRMWARE -

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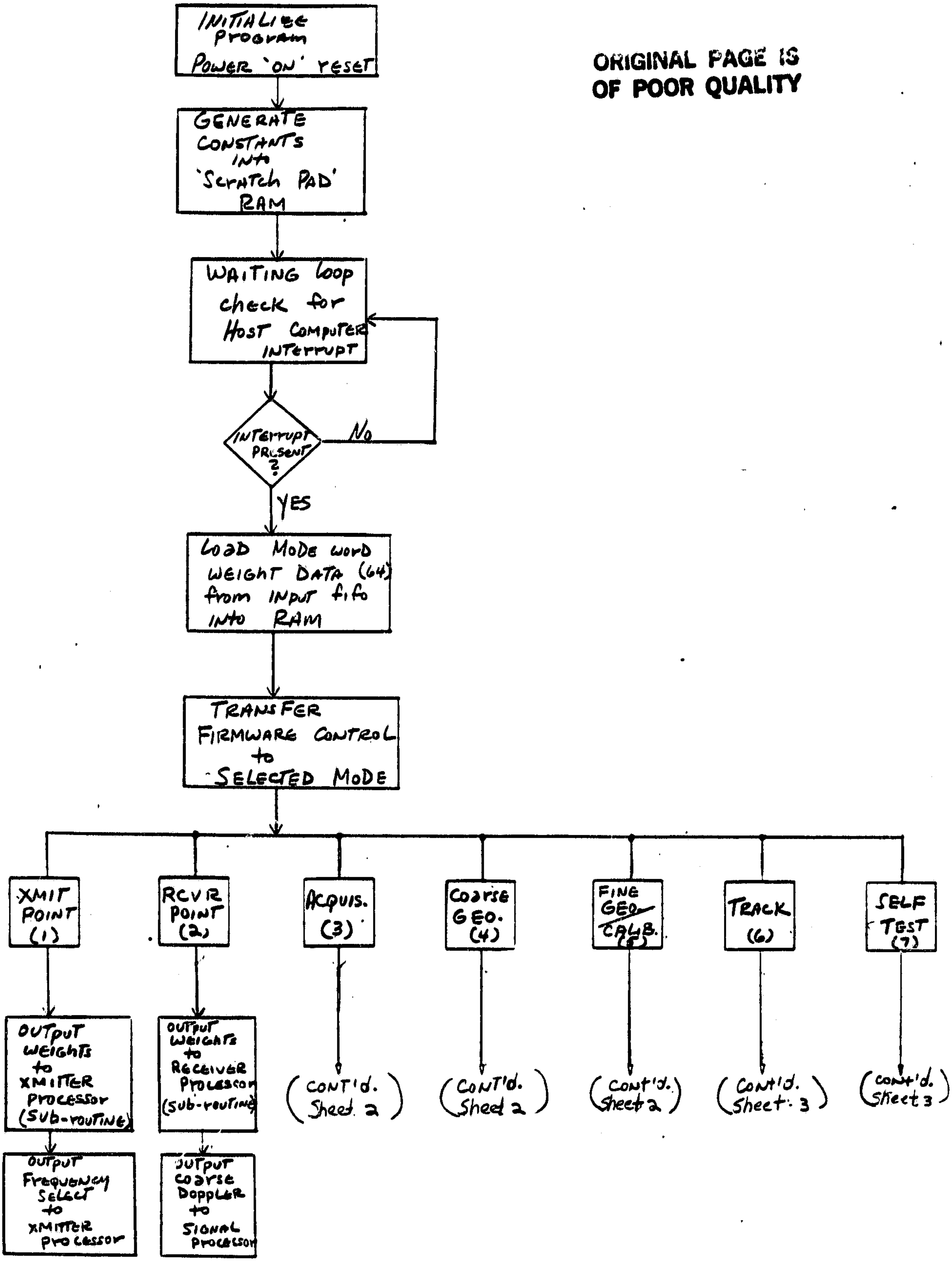

Figure 4-4

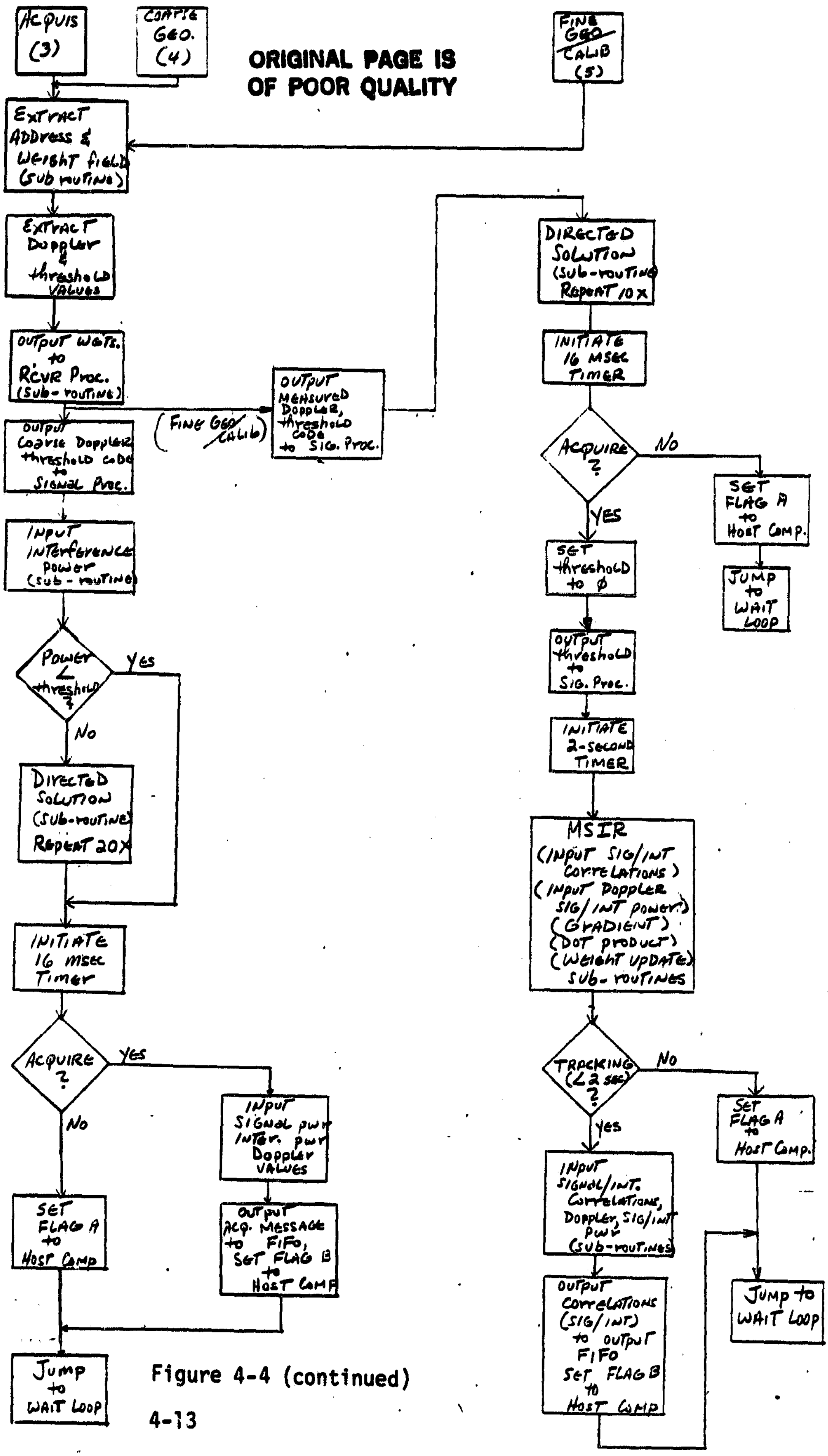

Figure 4-4 (continued)

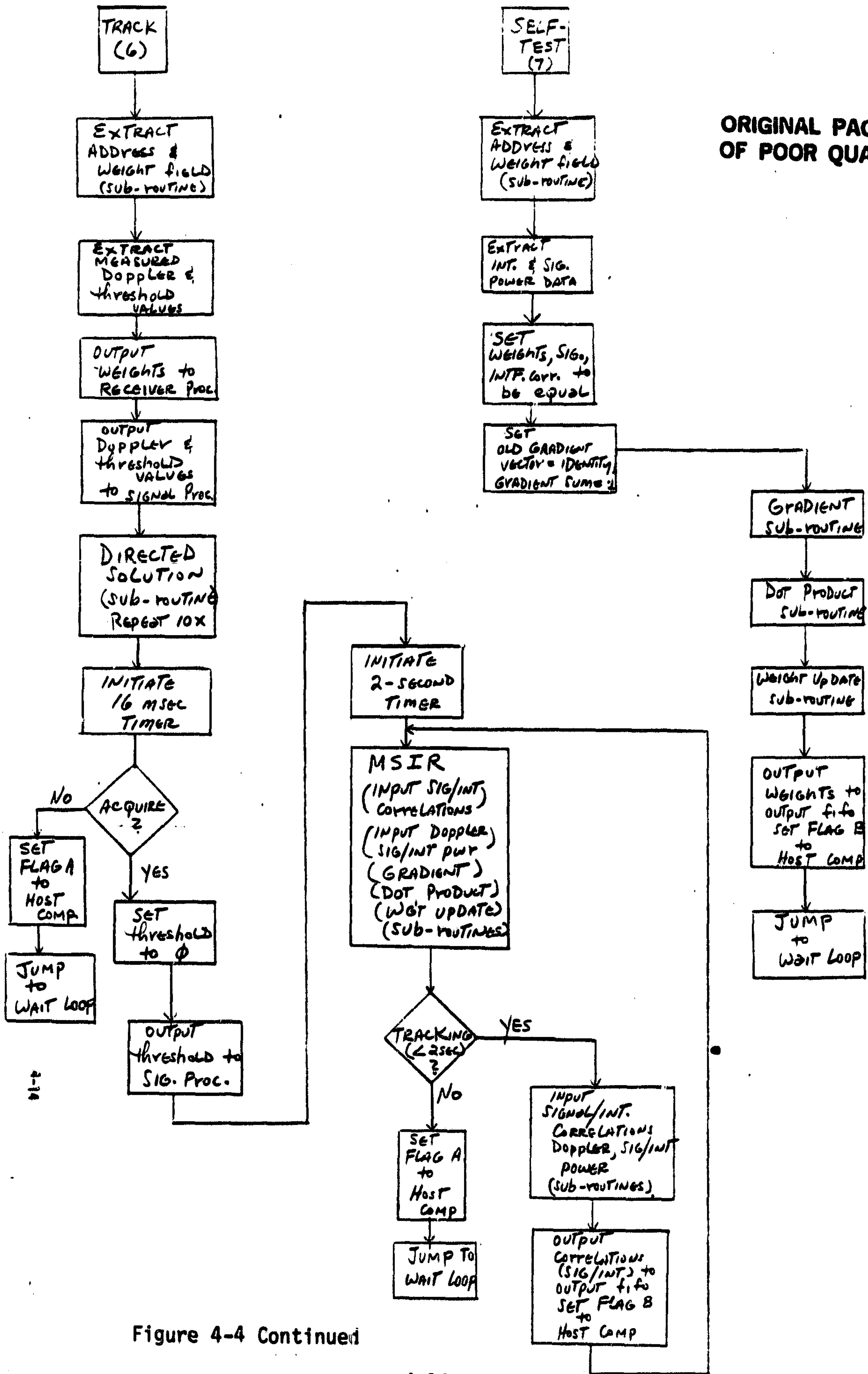

Figure 4-4 Continued

For transmit point or receiver point mode, outputting the weights to the respective processors (XMIT, Receive) is accomplished through the subroutine noted in the flow chart. The extraction of the address and weight field subroutine is also common to the other modes of operation. During acquisition mode, if the interference power is greater than the designated threshold, the Directed Solution algorithm will null out the 'interferer' after 'n' number of iterations. The output of the Directed Solution is a set of 64 weights. Prior to acquiring, a 16 millisec timer is initiated. The respective flags are then sent to the Host Computer (Flag A - no acquisition, Flag B - acquisition) and the firmware jumps back to "waiting" loop condition. Coarse geolocation is identical to acquisition mode with the exception of Doppler frequency word (acq = coarse doppler; Coarse Geo. = Measured Doppler). Pumping the weighted data into "output FIFO" is a general subroutine for sending information to the Host Computer - Flag B.

The MSIR (Maximum Signal to Interference Ratio) algorithm for 32 elements is used for Fine Geolocation, calibration and track modes. The input data (from the signal processor) consists of correlations, signal and interference power levels, all in 8-bit 2's compliment representation. The processing portion of the algorithm utilizes the gradient and dot product convergence technique, see Section 2.0. If tracking criteria fails after 2 seconds, Flag A (fail criteria) is generated to the Host Computer and the firmware jumps to the waiting loop. If tracking requirements are met, Flag B notifies the Host Computer of the 'pass' criteria, and data words are sent to the computer.

In the self test mode, the weights, signal and interference correlations are set equal to each other. The old gradient vector is set to $(1 + j0)$ and the old gradient is set to 1. The resultant calculated weights are then sent to the Host Computer for comparison with the prestored correct weights.

5.0 Tests and Test Data

The test procedures that were generated to evaluate the AMPA hardware and software performance were divided into three separate volumes:

Volume I - STE Test Procedures

Volume II - Software Test Procedures

Volume III - Experimental Model Test Procedures

Tests were conducted on the STE & Software informally (AIL engineering personnel only) using Volumes I & II. Raw data for the STE and software testing is included in Appendix B. Abbreviated informal and formal engineering tests (AIL and NASA personnel) were run in lieu of Volume III.

5.1 Subsystem Testing

Measurements were made on the four User Terminal Simulators to determine their characteristics. Antenna gain at the transmit and receive frequencies (4.1)*, cable losses (4.2), noise figure (5.1), and transmitted power at both frequency channels for CW and PN code (6.1, 6.2, 6.3) were measured. This data was used to calculate the respective G/T and ERP of each user terminal.

Modulation characteristics of the User Terminal Simulators in transmit and receive modes was demonstrated (7.1, 7.2, 7.3 and 7.4). The data shows the capability of each User Terminal Simulator to operate in CW, Delta Modulation, BPSK and FM data modes. The BERT (7.5) units on each User Terminal Simulator were also

*(a.b) corresponds to test data sheet paragraphs in Appendix B.

checked. Duplex operation, ie., simultaneous receive and transmit was also verified (8.0). The interference source power was also measured to verify its operation (9.2 and 9.3). The Manual Test Rack operation was also demonstrated (10.0).

The software test procedure was run both informally and with NASA present. All operations and parameters tested successfully. During engineering debugging the Communication modes for the Experimental Model were successfully tested. (Refer to Log Notebook 1/6/81). In addition, the receive gain and noise figure of each element of the array was calculated using a set up that measured tangential sensitivity (refer to Log Notebook 12/12/80, 1/27/81 and 1/29/81). Data was also taken for transmit operation (refer to Log Notebook 12/11/80).

5.2 System Configuration

There were some element failures which limited the array to 30 elements on receive and 27 elements for transmit.

In order to achieve the most useful data, modifications were made to the STE to run Experimental Model testing. The transmitter amplifier of User Terminal Simulator #1 was used as the LO driver for User Terminal Simulator #2 to provide higher LO power. This improved the User Terminal Simulator #2 receiver sensitivity by 25 dB.

An additional modification was made to the interference source. Its output was fed to the User Terminal Simulator #4 transmitter amplifier to boost interference power to accomodate the required interference ERP. With two User Terminal Simulators used in the test setup, two User Terminal Simulators and one interferer were left as test sources. Each of these units could be connected

to User Terminal Simulator #1 antenna or Interferer B antenna, etc. The experimental model contained EROMS instead of the final PROMS. This limited the speed of the processing algorithm.

5.3 Performance Demonstration Testing

The Experimental Model testing began with calibration. Calibration was run for all four beams. The calibration data for Receive Beam A and Receive Beam B were similar so that one set of data (Table 5.1) labeled UTS 2BS was used. A file for manually pointing in the static point mode at User Terminal Simulator #3 was also generated from calibration data. This data (Table 5.2) is labeled UTS 3SL. Calibration data taken for transmit beams A & B were different and they are tabulated in Tables 5.3 and 5.4.

Phase calibration is required to permit accurate static pointing while phase and amplitude calibration is required to permit nulling. Calibration was accomplished by using a single element as a reference and adjusting and measuring the phase and amplitude of another element until the summed signal of the two elements was nulled. The phase differences between the elements can be related to a specific geometry for the array.

An additional calibration or setting of the correlator sum and sample input phase lengths is required so that the correct sense and magnitude of the gradient can be calculated accurately. This was accomplished by receiving a single signal (i.e., into element #2 only) and adjusting the sum correlator input phase so that the signal and interference correlations of sum to sample equaled the weight setting. This was accomplished during debugging.

Table 5.1

8-31-81 Receiver Calibration

UT#2 - Boresight

	Amplitude	Phase	λ *		Amplitude	Phase	λ
1.	.5827	-232.0	-.6444	17.	.3622	169.0	.4694
2.	.0787	-294.0	-.8167	18.	.6457	181.0	.5028
3.	.6929	-79.0	-.2194	19.	.6378	170.5	.4736
4.	.3071	-176.0	-.4889	20.	.1181	112.5	.3125
5.	1.0236	285.5	.7931	21.	.2283	112.5	.3125
6.	Reference			22.	.6535	180.5	.5014
7.	.4961	-25.5	-.0708	23.	.5354	-104.5	-.2903
8.	.0945	137.0	.3806	24.	.4252	-7.5	-.0208
9.	1.0787	-51.5	-.1431	25.	No Signal		
10.	.2992	-27.0	-.0750	26.	.6378	182.0	.5056
11.	1.0945	53.5	.1486	27.	.3780	-47.5	-.1319
12.	.3858	-134.0	-.3722	28.	.3622	-9.5	-.0264
13.	.4016	-149.0	-.4139	29.	.5197	57.5	.1597
14.	.4173	2.0	-.0056	30.	.4567	-123.0	-.3417
15.	.4567	-69.0	-.1917	31.	Inoperative		
16.	.9449	-159.0	-.4417	32.	.3622	-84.5	-.2347

* λ is the wavelength that corresponds to the phase and is the parameter that is entered in the software calibration algorithm.

Table 5.2

8-31-81 Receiver Calibration

UT#3

	Amplitude	Phase		Amplitude	Phase
1	.7008	80.0	18.	.4016	163.5
2.	.1260	8.5	19.	.2283	87.0
3.	.6614	197.0	20.	.0709	111.5
4.	.1102	-23.0	21.	.0709	81.0
5.	Intermittent Signal		22.	.2283	112.5
6.	Reference		23.	.2756	200.5
7.	.4409	-98.0	24.	.2992	96.5
8.	.0945	-215.5	25.	No Signal	
9.	1.1339	-143.5	26.	1.1260	13.0
10.	.2283	-154.0	27.	.1102	150.5
11.	.7874	89.0	28.	.0709	126.0
12.	.3307	184.0	29.	.2283	-147.5
13.	.1496	94.5	30.	.3780	-10.0
14.	.1732	11.0	31.	Inoperative	
15.	.4173	-49.0	32.	.1969	61.0
16.	.7165	107.0			
17.	.1969	95.5			

Table 5.3

12-2-81 Transmit Calibration B

	Phase	Element Amplitude		Phase	Element Amplitude
1.	180°	.2677	17.		
2.	-25.0	.2756	18.	-135.5	.9134
3.			19.	-176.0	1.1102
4.	23.5	.1969	20.	14.0	1.1890
5.			21.	-117.0	.4252
6.	163.5	0.7953	22.		
7.	4.0	1.1181	23.	237.0	1.5591
8.	Reference		24.		
9.	256.0	2.4567	25.	89.0	1.0157
10.	9.5	2.2283	26.	146.0	1.5748
11.	-251.5	0.1260	27.	-168.5	1.0866
12.	-67.0	1.787	28.	122.5	0.5276
13.	-51.0	.7717	29.	261.5	0.6063
14.	-203.0	.5276	30.	88.0	0.6850
15.	-173.0	.6299	31.		
16.	-37.0	.3780	32.	21	1.0787

Table 5.4

12-2-81 Transmit Calibration A

	Angle	Amplitude		Angle	Amplitude
1.	182.5	.2362	17.		
2.	0	.6378	18.	-121.0	.6614
3.			19.	-159.0	.9055
4.	-13.5	.2441	20.	11.0	.8583
5.			21.	-104.0	.8268
6.	178.0	.5591	22.		
7.	15.0	.8268	23.	-144.0	.7165
8.	Reference		24.	244.0	3.5830
9.	-97.5	2.6299	25.	99.0	.7559
10.	46.0	1.3788	26.	137.0	1.2992
11.	142.0	.1654	27.	187.0	.9291
12.	-27.5	.3386	28.	-225.5	.5276
13.	-19.5	.7244	29.	-90.5	.6929
14.	-192.0	.7953	30.	-261.5	.1969
15.	-161.0	.7323	31.		
16.	-6.0	.3386	32.	16.0	2.2520

5.3.1 Static Modes

"Formal" testing begain with static pointing and beamwidth measurements. Refer to Figure 5-1 for the scenario. Receive Beam A (30 elements) was pointed at boresight (0° elevation, 0° rotation), which was the location of User Terminal Simulator #2. Two antenna pattern runs were taken (due to readjustment of the pattern recorder). Another run was taken using User Terminal Simulator #1 as boresight. The beamwidth ranged from 6.0° to 6.2°. These patterns are shown in Figures 5-2, 5-3, and 5-4 respectively. A previously run pattern, Figure 5-5, for 16 elements showed that the receive beamwidth broadens to 9° which is to be expected for the smaller aperture.

Receive Beam A (30 elements) was also commanded to point at 45° elevation and 0° rotation while boresighted at User Terminal Simulator #2. The pattern, Figure 5-6, shows the beamwidth broadening to 9°. Pointing accuracy is 0.5° using the scale on the recorded pattern as a reference. The wideband array output sum S/N appears to have limited the dynamic range of the recorder so that deep nulls are not presented on the patterns.

Transmit Beam B (27 elements) was used to demonstrate static transmit pointing. Figure 5-7 is a plot of the antenna pattern which shows the beamwidth at Nadir to be 5°. A previously run pattern, Figure 5-8, shows the transmit pointing beamwidth broadens with smaller apertures and less elements. Figure 5-9 is a pattern of the Transmit Beam B (27 elements) pointed at 50° elevation, 0° rotation. It shows the beamwidth broadening to 9°, a pointing accuracy of 1° and a scan loss of 6 dB. All the above plots show that the static pointing mode performs successfully for both receive and transmit.

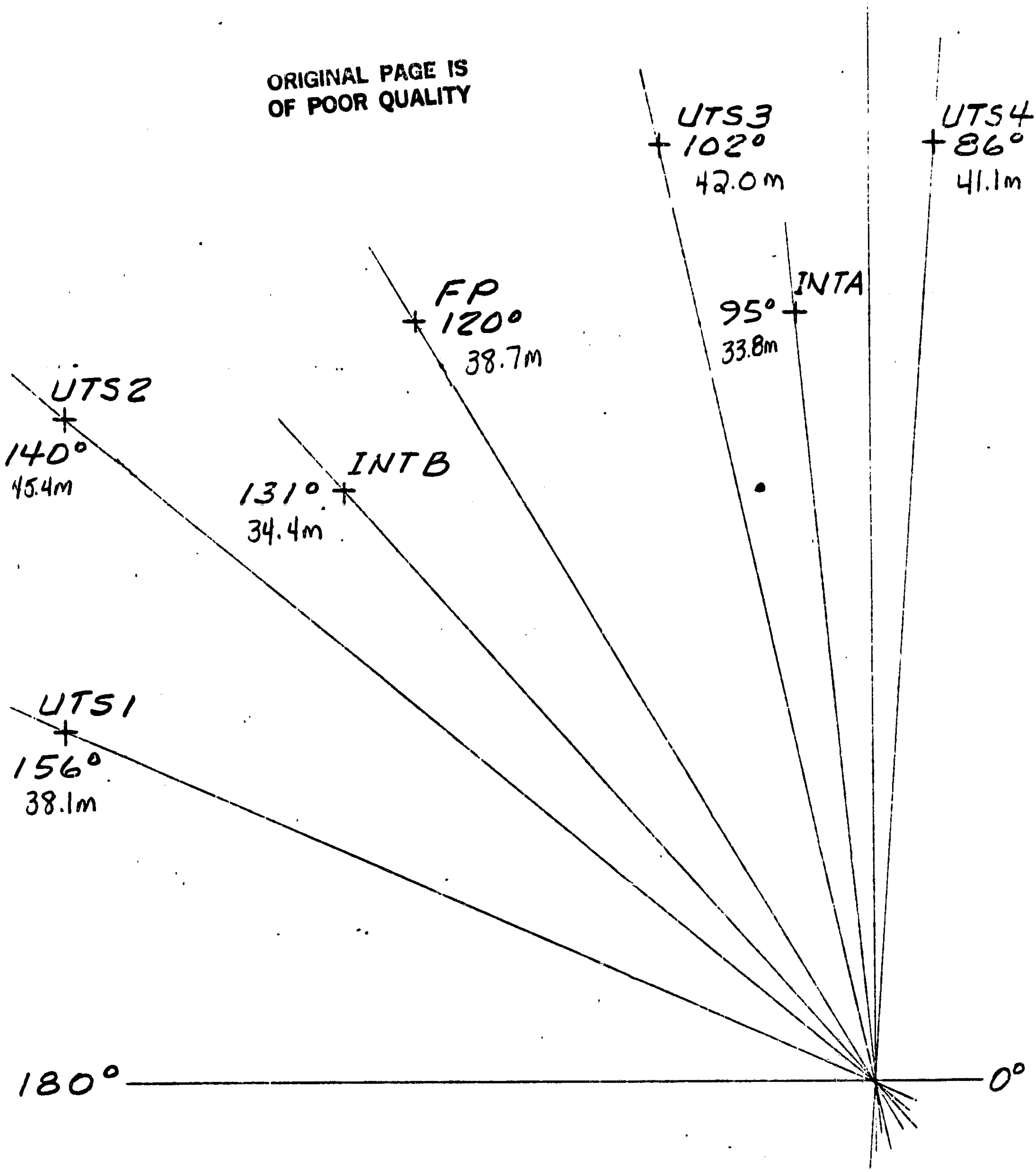

Figure 5-1
AMPA Test Range

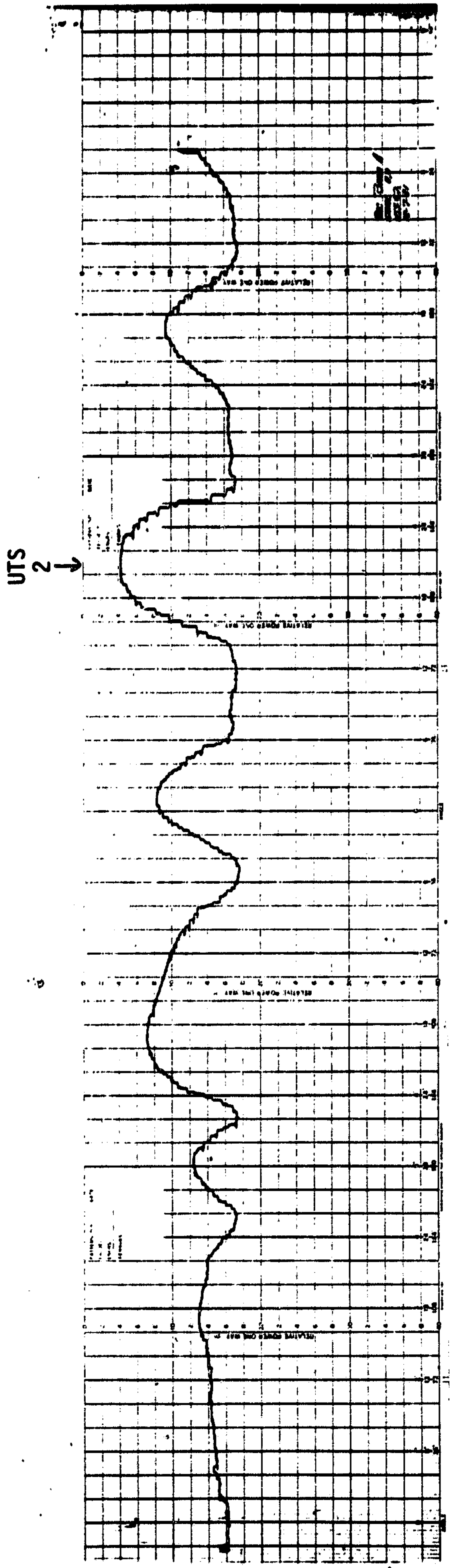

Figure 5-2
Receive Beam A -
Pattern #1

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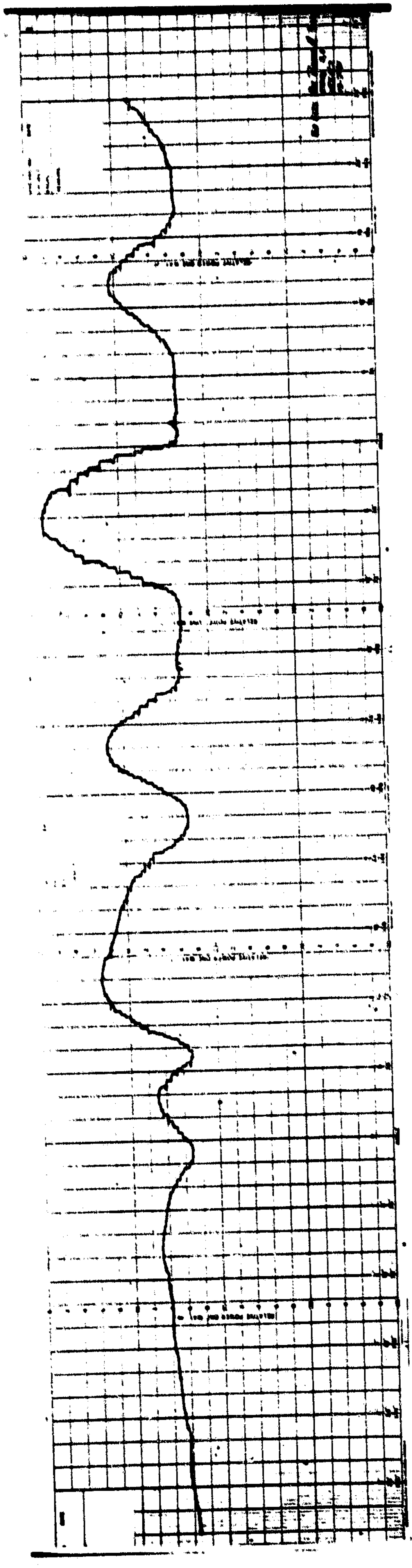

Figure 5-3
Receive Beam A -
Pattern #2

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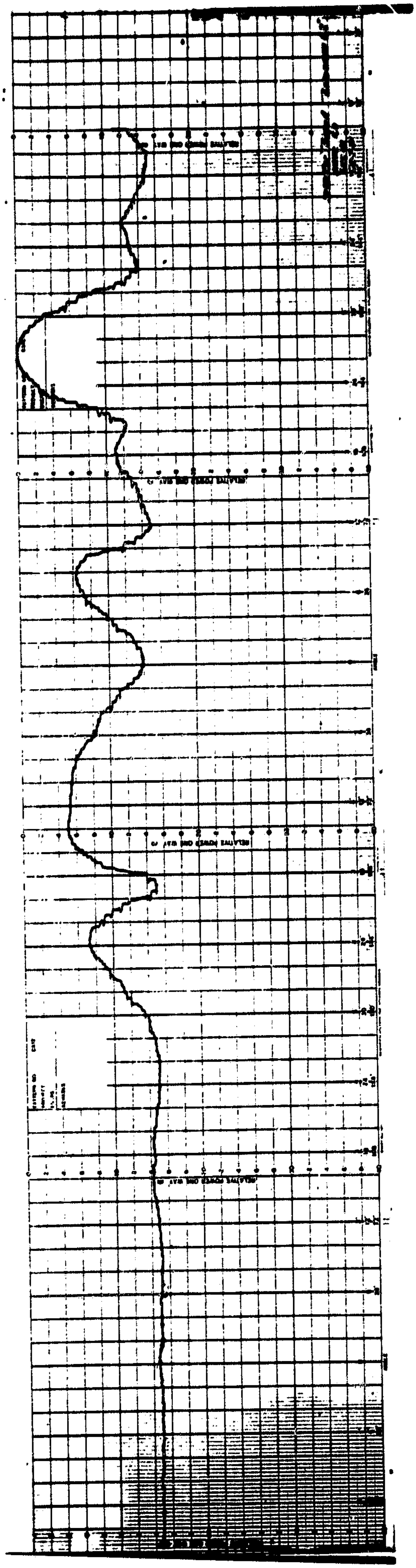

Figure 5-4
Receive Beam A -
Pattern #3

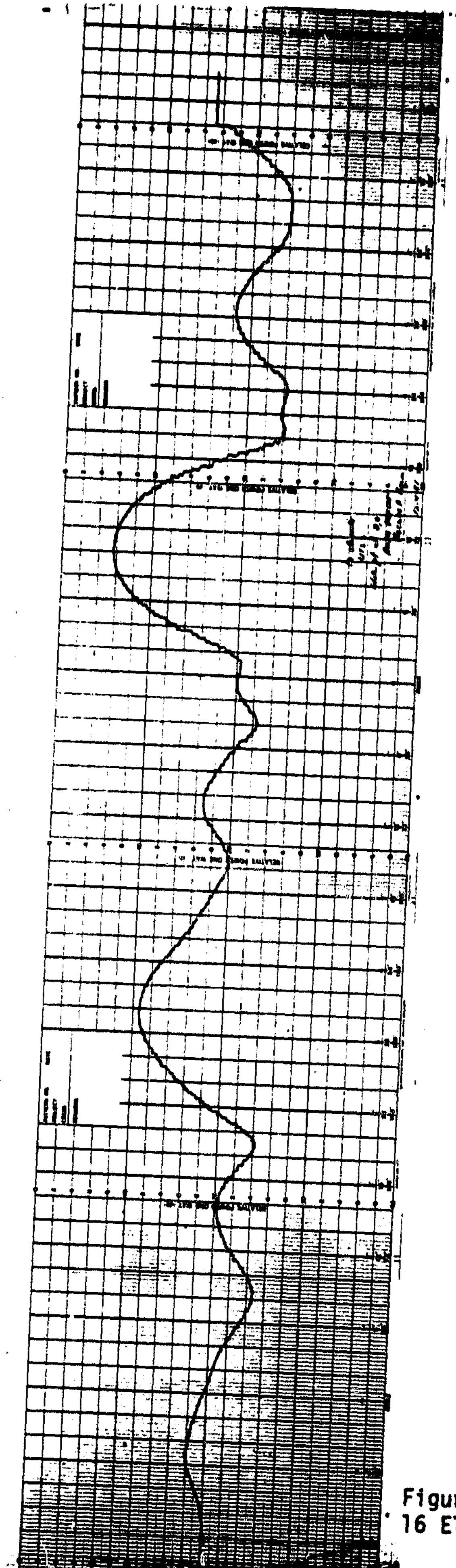

Figure 5-5
16 Element Pattern

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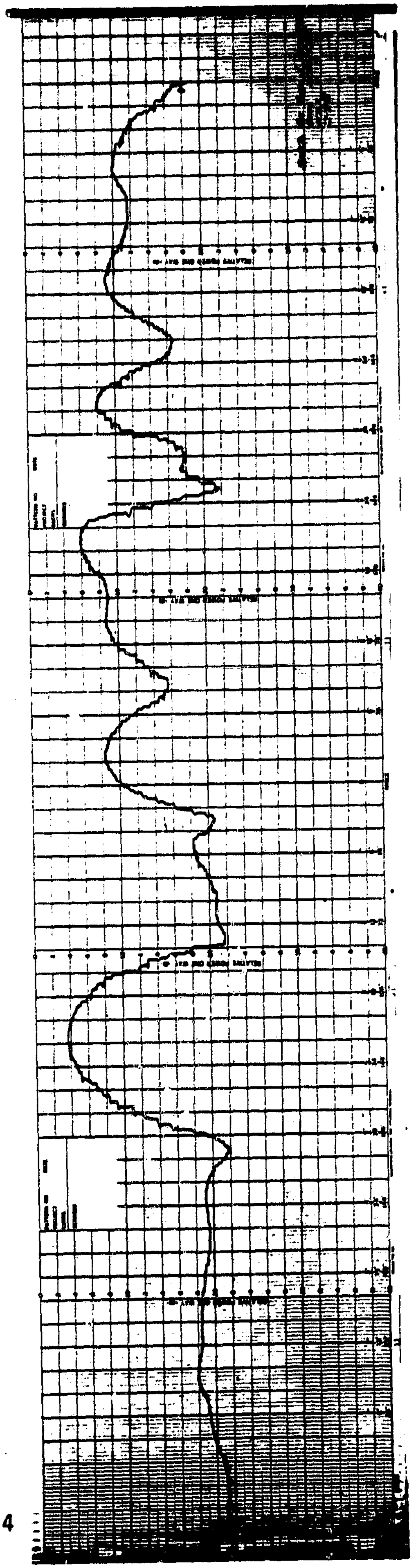

Figure 5-6
Receive Beam A - 30 Elements
Pointed at 45°

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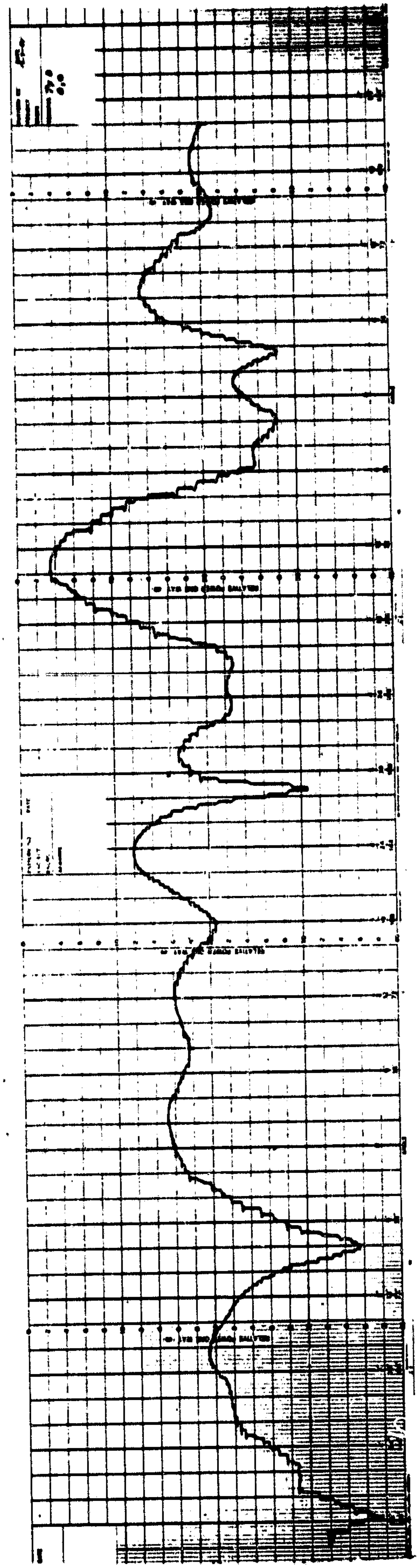

Transmit Beam B
(27 Elements)
Static Pointing

Figure 5-7

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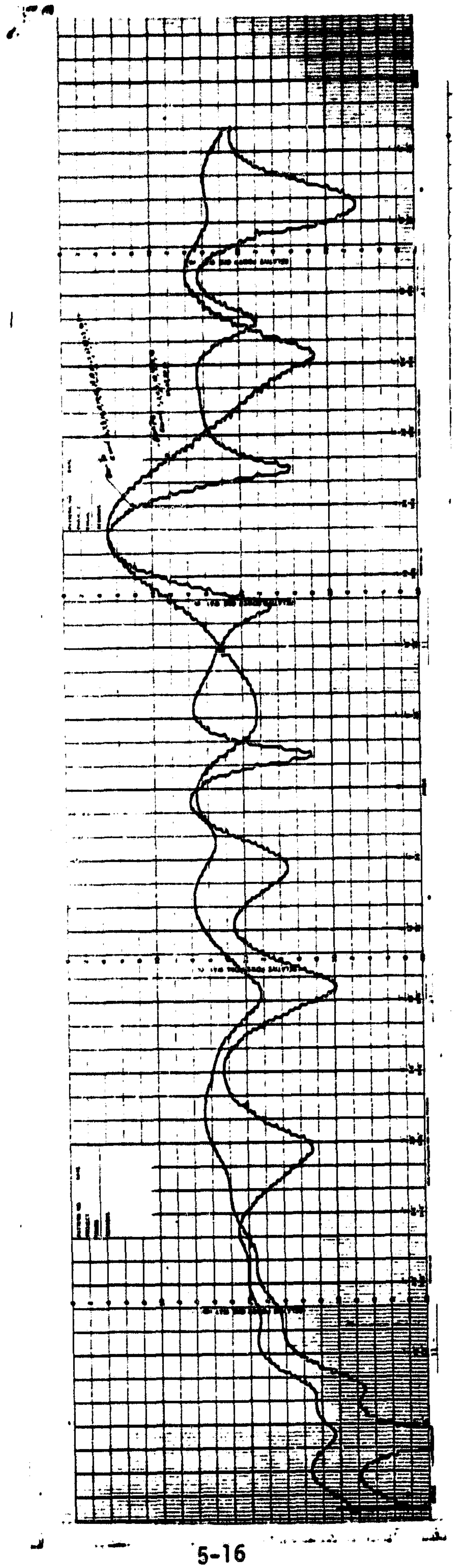
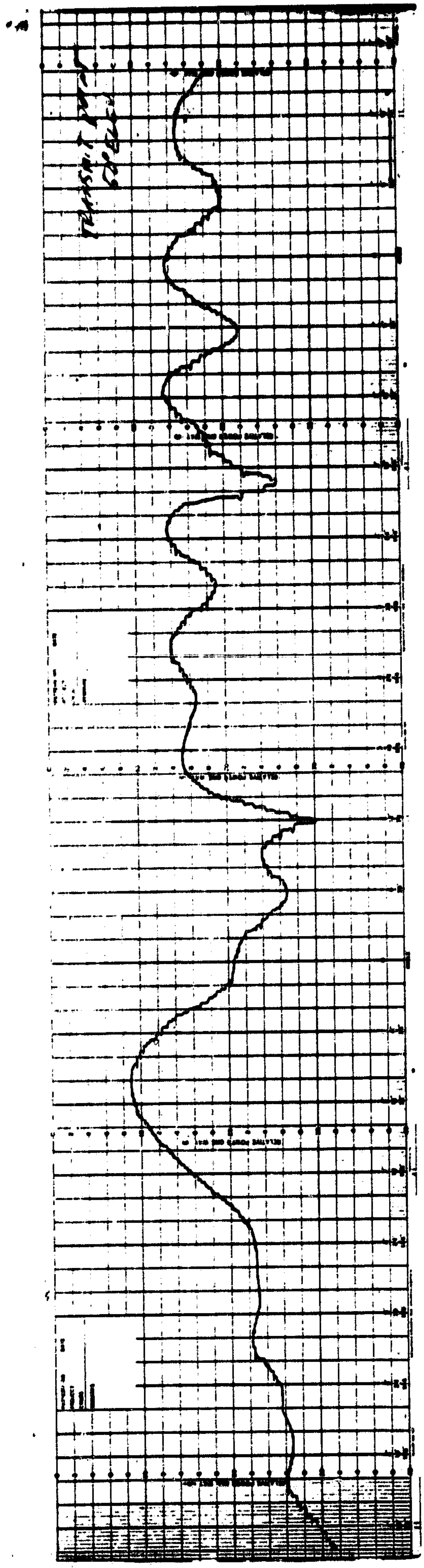


Transmit Pattern with Less Elements

Figure 5-8



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Transmit Beam B -
Pointed at 50°

Figure 5-9

5.3.2 Adaptive Modes

Testing continued with a demonstration of tracking and acquisition using spectrum analyzer photographs and antenna patterns. The receive beam A was asked to acquire and track the test scenario shown in Figure 5-10, which is a single User Terminal Simulator transmitting in Delta modulation at boresight and an interferer transmitting CW at 9° from boresight. Figure 5-11 shows the improvement of S/N+I after acquiring the uniquely coded UTS signal and nulling the interferer. The above was repeated using CW data modulation for Beam B to show that acquisition occurred for both PN code types. This is shown in Figure 5-12 which shows the test scenario and Figure 5-13 which shows the result, i.e., 35 dB improvement in S/I+N.

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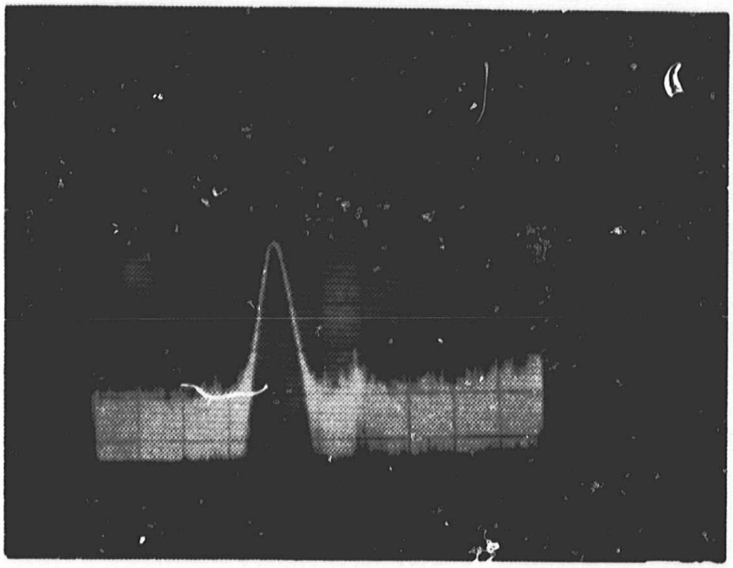

Figure 5-10 Sum Output of Receive Beam A Element #2 with UTS 2 and Interferer at INT B, UTS in Δ Mod Mode

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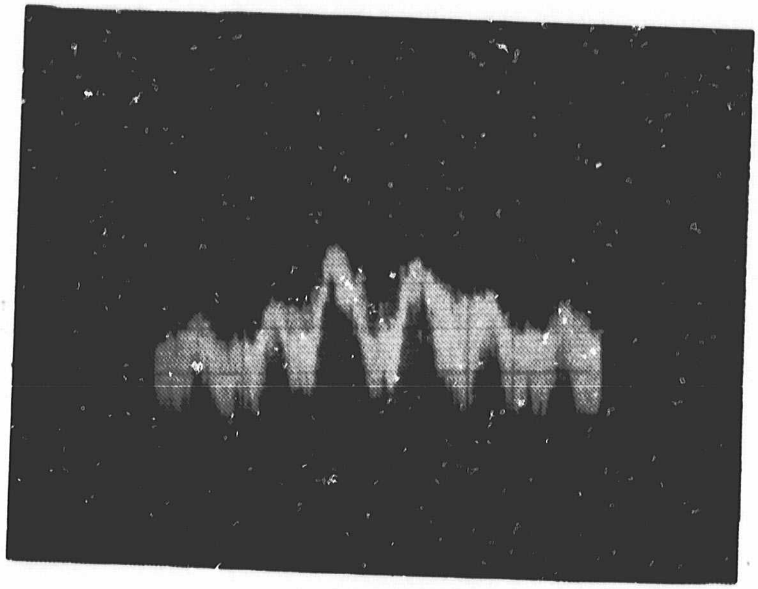

Figure 5-11 Sum Output of Receive Beam A 30 Elements for scenario Generated in Figure 5-10, After Acquisition & Tracking

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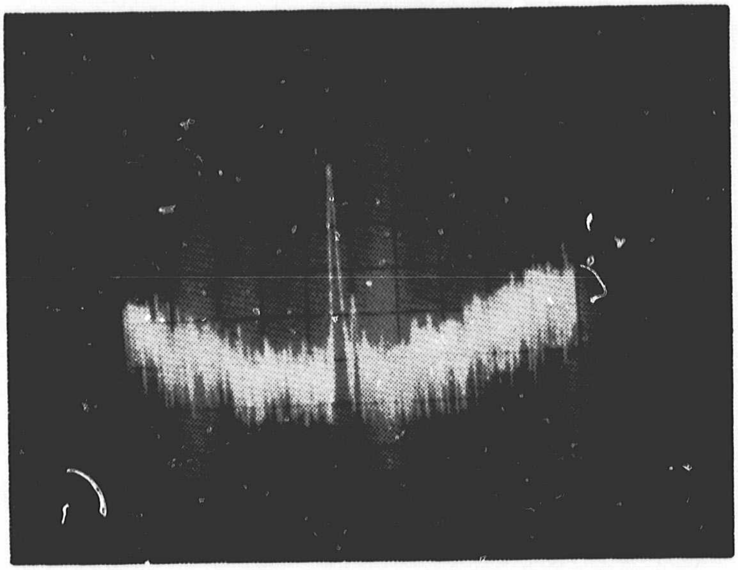

Figure 5-12 Sum Output of Receive Beam B - Element #2, with UTS 2 and Interferer at INT B. UTS in CW Mode

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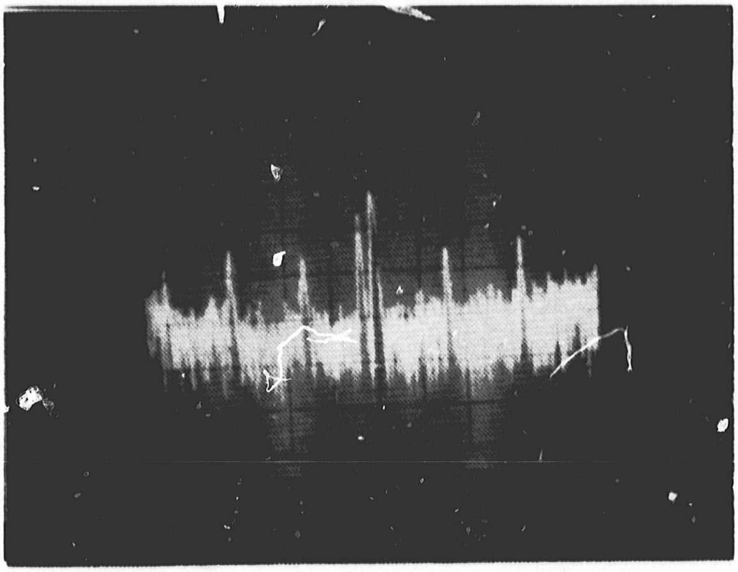
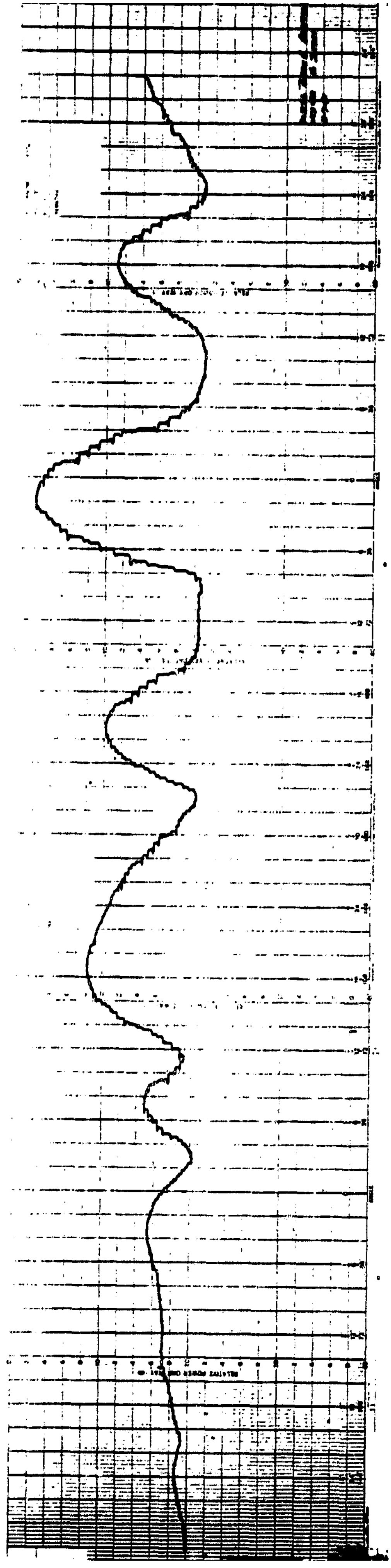


Figure 5-13 Same Output of Receive Beam B (30 Elements) for Scenario Generated in Figure 5-12 - After Acquisition and Tracking.

Using the "FREEZE" command for the receiver processor weights, a pattern was taken of Receive Beam A with no interferer in the adaptive mode to compare it to static pointing modes. This pattern is shown in Figure 5-14. The beamwidth appears to have narrowed to 5.5° from 6° to 6.2° (static pointing). Figure 5-15 is a photo of the no interference sum output of receive Beam A after acquisition and tracking. Several patterns and photographs were taken to measure the S/I+N improvement and antenna nulling after adapting with the interferer placed at 9° away from the desired signal and 20° away. The data is shown in Figures 5-16 and 5-17 for the 9° case and Figures 5-18 and 5-19 for the 20° case. The peak is shifted slightly due to the MSIR algorithm. The problem that was solved for these cases for Beam A is similar to that shown in Figure 5-12 for Beam B. The patterns tend to show a broadening of nulls. However, since the recorder dynamic range was limited by the S/N sum output, no deep nulls could be displayed. The photographs show S/N+I improvements of 32 and 36 dB respectively.

An additional pattern, Figure 5-20, was run for the case of the interferer placed at User Terminal Simulator #3, 38° away from boresight. Here the pattern shows that the natural peaks of the antenna were reduced.

Frequency reuse was demonstrated. The problem is shown in Figure 5-21 and the respective Beam A and Beam B outputs after adapting are shown in Figures 5-22 and 5-23 respectively. Beam A adapted to User Terminal Simulator #3 and Beam B adapted to User Terminal Simulator #2. Previously run results were also successful with the interferer at Int A (close to User Terminal Simulator #3). This is shown in Figures 5-24, 5-25, and 5-26.



Receive Beam A -
No Interferer
Figure 5-14

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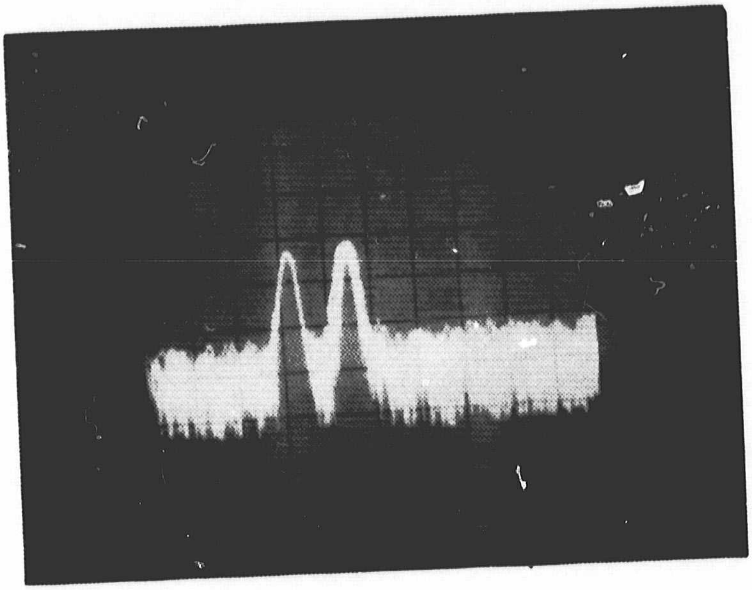

Figure 5-16 Receive Beam A Sum Output - 30 Elements for Similar Scenario Generated in Figure 5-12 Interferer at INT B - After Acquisition & Tracking

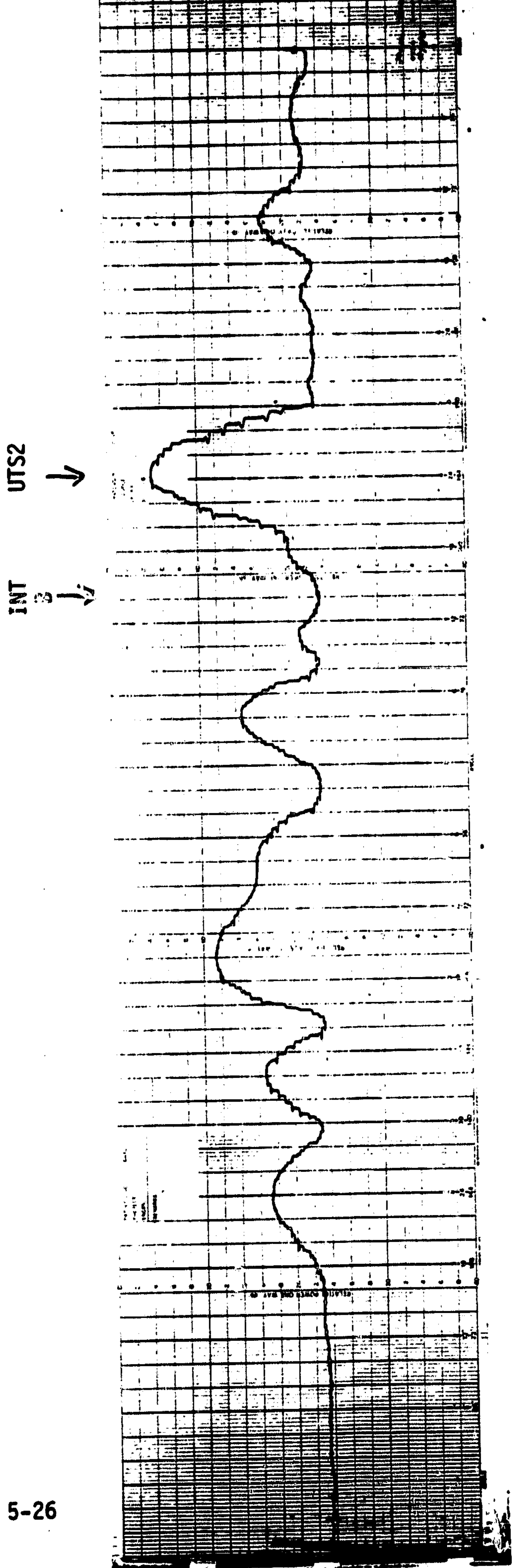

Figure 5-17
Interferer at 9°

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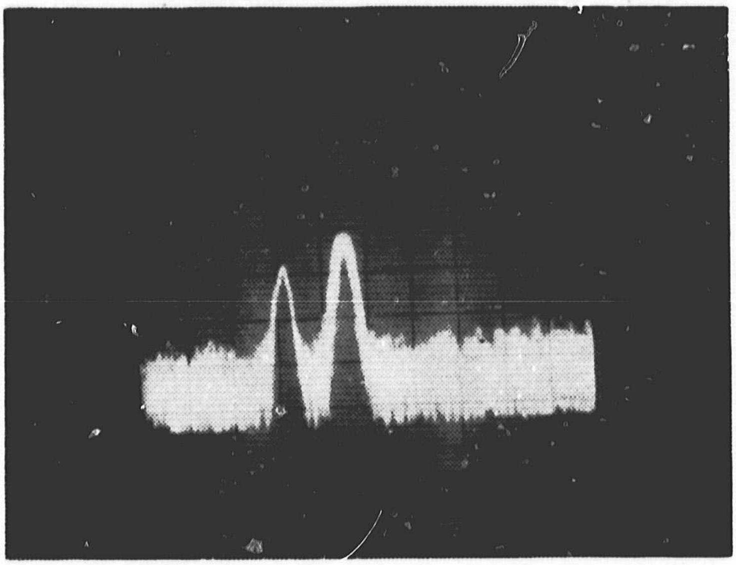
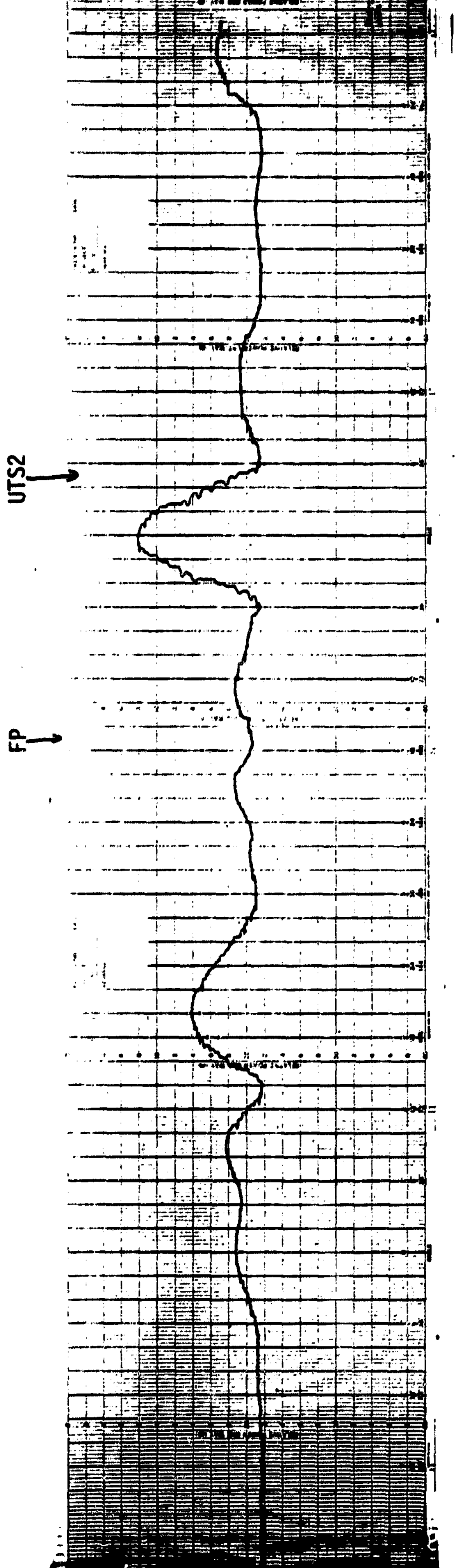


Figure 5-18 Receive Beam A - Sum Output 30 Elements for Similar Scenario Generated in Figure 5-12 - After Acquisition & Tracking. Interferer at FP.



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Interferer at 20°
Figure 5-19

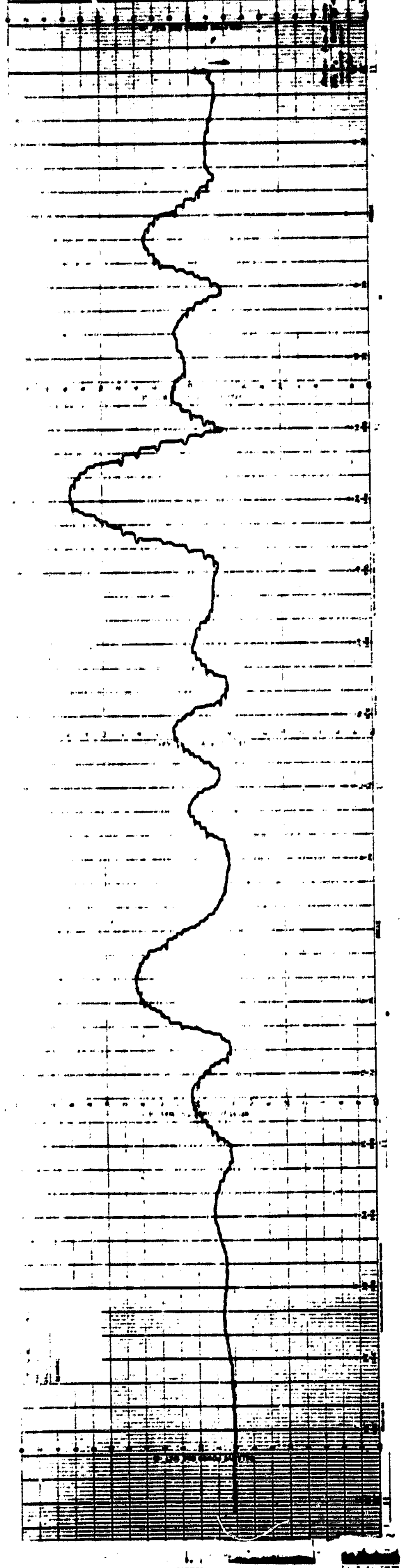

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Figure 5-20
Interferer at User Terminal #3
(38° away)

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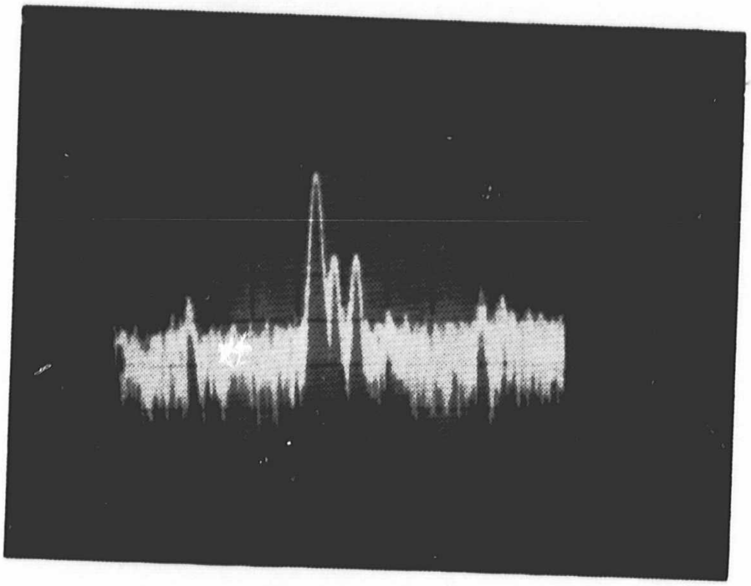

Figure 5-21 Element #2 Output Showing Int B, UTS #2, UTS #3, at same frequency channel.

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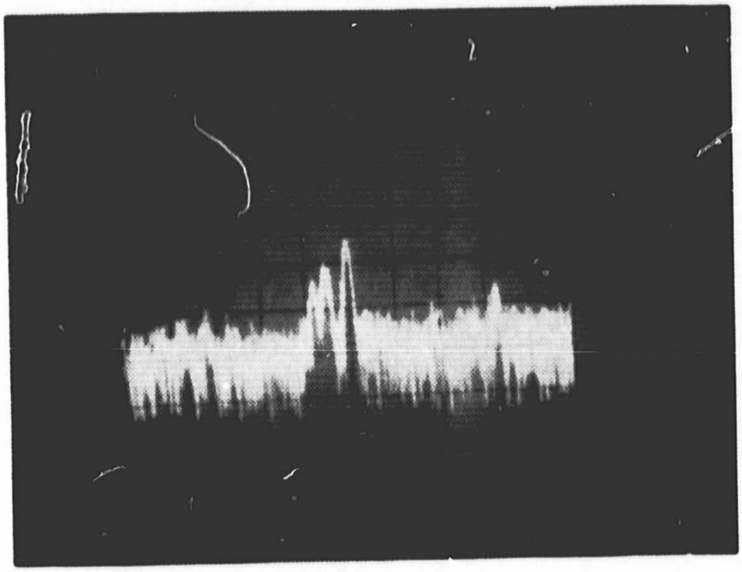

Figure 5-22 Beam A Sum Output After Acquisition & Tracking of UTS #3 for scenario in Figure 5-21. S/I Improvement of 30 dB.

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Figure 5-23 Beam B Sum Output After Acquisition & Tracking of UTS #2 for Scenario in Figure 5-21. S/I Improvement of 23 dB.

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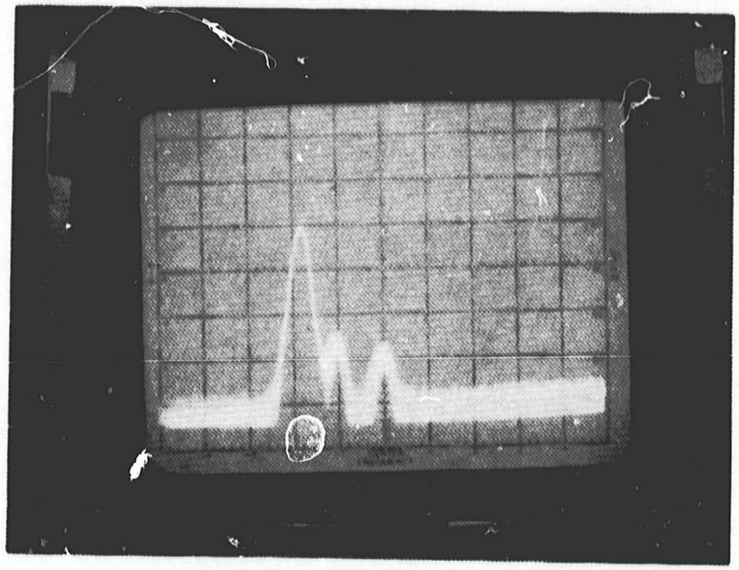

Figure 5-24 Element #2 Output
INT A, UTS #2, and UTS #3
at Same Frequency Channel

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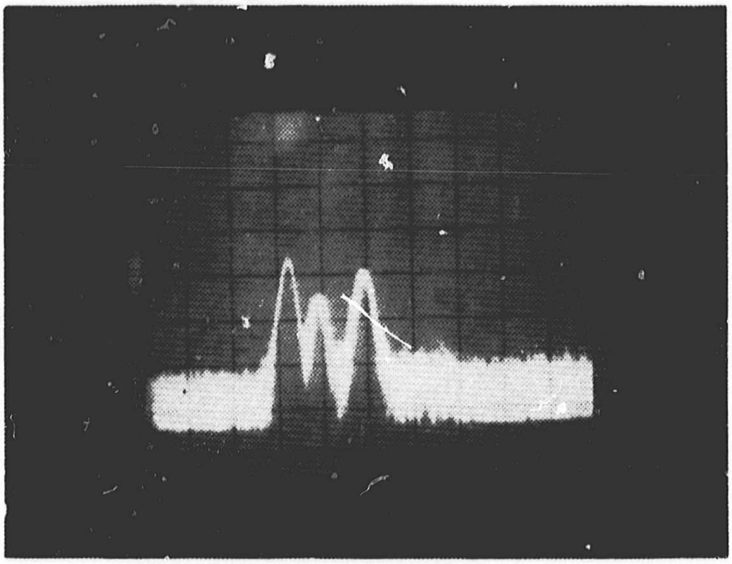

Figure 5-25 Beam A Sum Output
After Adapting to UTS #3
for Scenario of Figure 5-24.
S/I Improvement of 24 dB.

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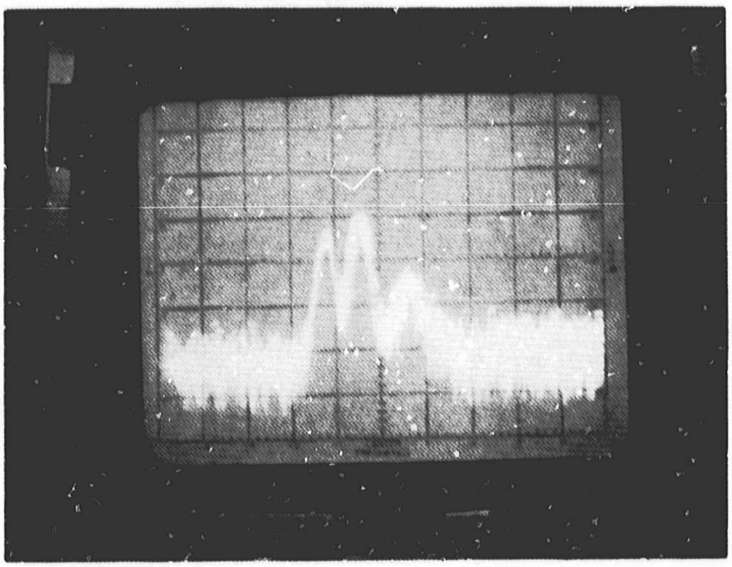


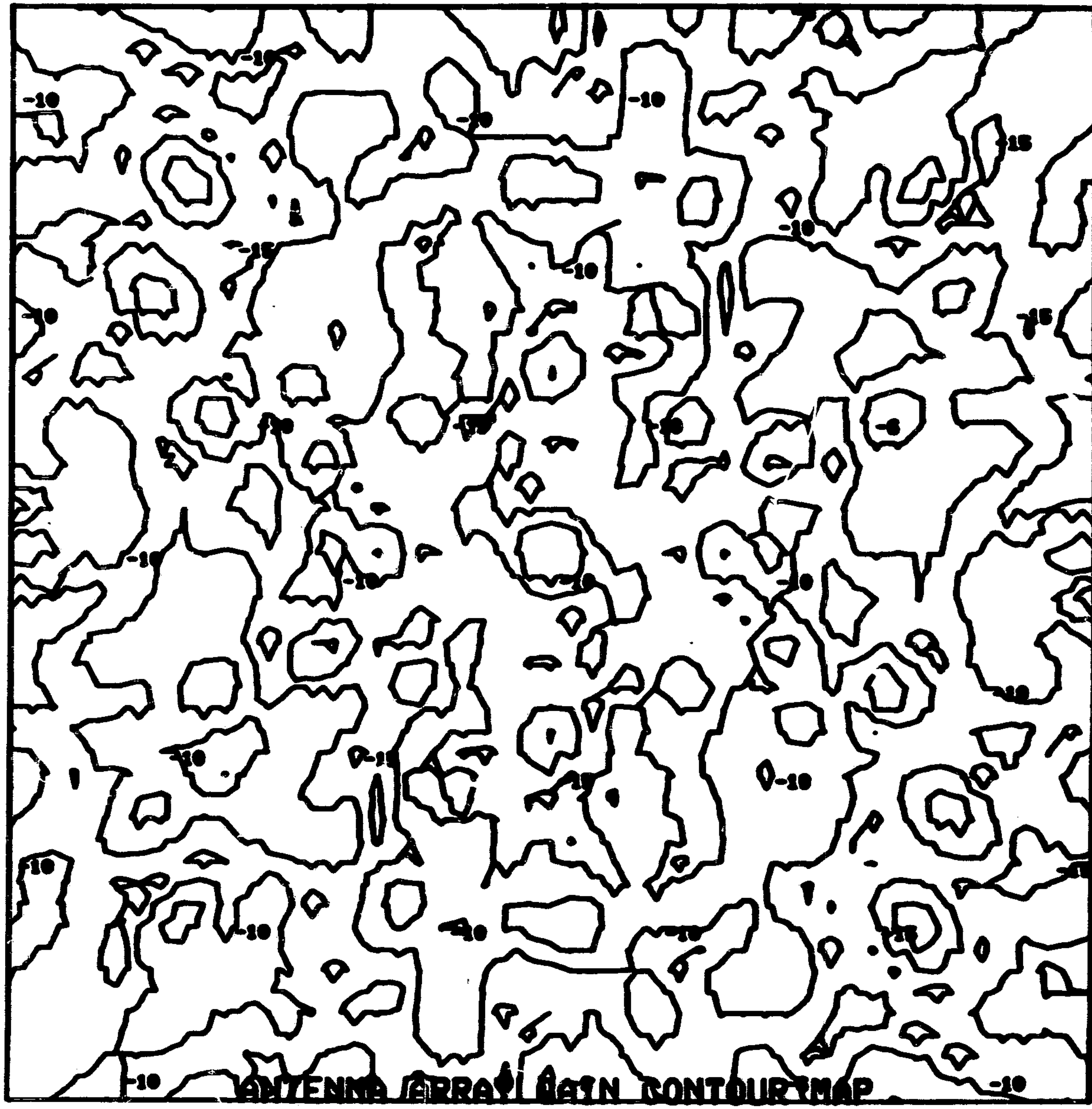
Figure 5-26 Beam B Sum Output After Adapting to UTS #2 for Scenario in Figure 5-24. S/I Improvement of 30 dB.

The effect of adapted array performance on the demodulated output for BPSK modulation was also demonstrated. The scenario consisted of one interferer at Interferer A. User Terminal Simulator #2 transmitted external BPSK - an 8 kHz squarewave using a 32 kHz clock. The demodulated output was completely wiped out by the interference. However, when adaptation occurred, the demodulated output quality was equivalent to that of no interference. This was done for both channels.

The AMPA software was also run to simulate scanning the earth's field of view. The system acquired and tracked. Antenna plots were generated from the weights for both clear and interference environments. These are shown in Figures 5-27 through 5-32. The plots show a peak where the signal is and a null where the interferer is.

Because of limited time, a single attempt was made to run the transmit null algorithm. It was not successful.

Dynamic tracking capability of the adaptive mode was demonstrated on Beam A by rotating the pedestal in a 110° arc past User Terminal Simulator #2 while maintaining signal lock. Tracking was also attempted with the interference source on, but lock could not be maintained. This is attributed to ringing of the pedestal servo and the use of EROMS which necessitated slower processing time.



PLOT DATA

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ROT.= 0.00 DEGREES
RADIUS= 60.00 DEGREES
RESOLUTION= 50 X 50 SUBMAPS

OMSC UPDATE= 3.20 SEC

TAPE 07-DEC-81 18:33:17
TRACK BM A PKT 6. RBG 2
PACKET TIME 00:00:03
FREQ= 1646.[illegible] MHZ

UTS #2 @ Boresight
Acquired No Interferer

Figure 5-27

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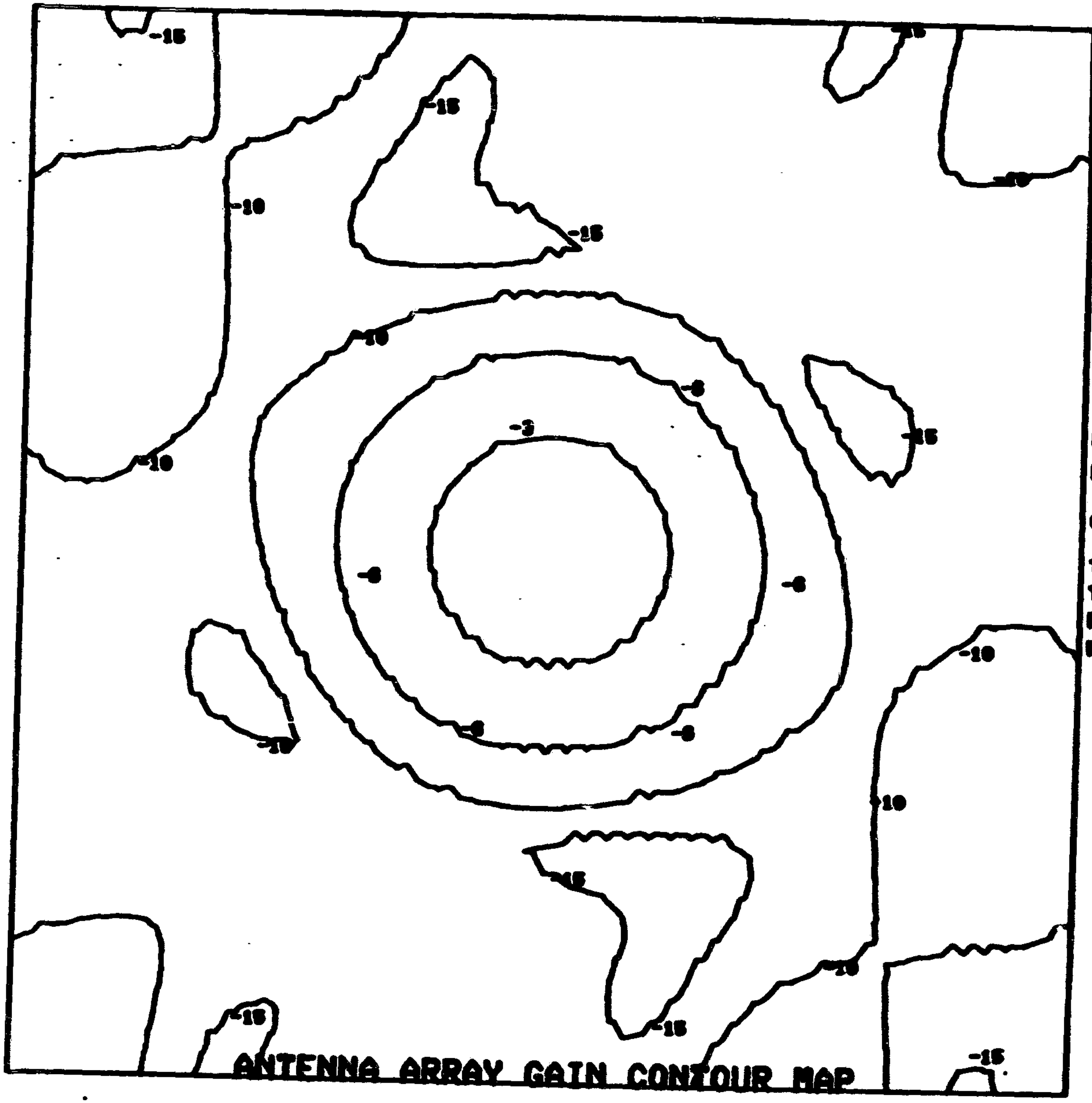

PLOT DATA

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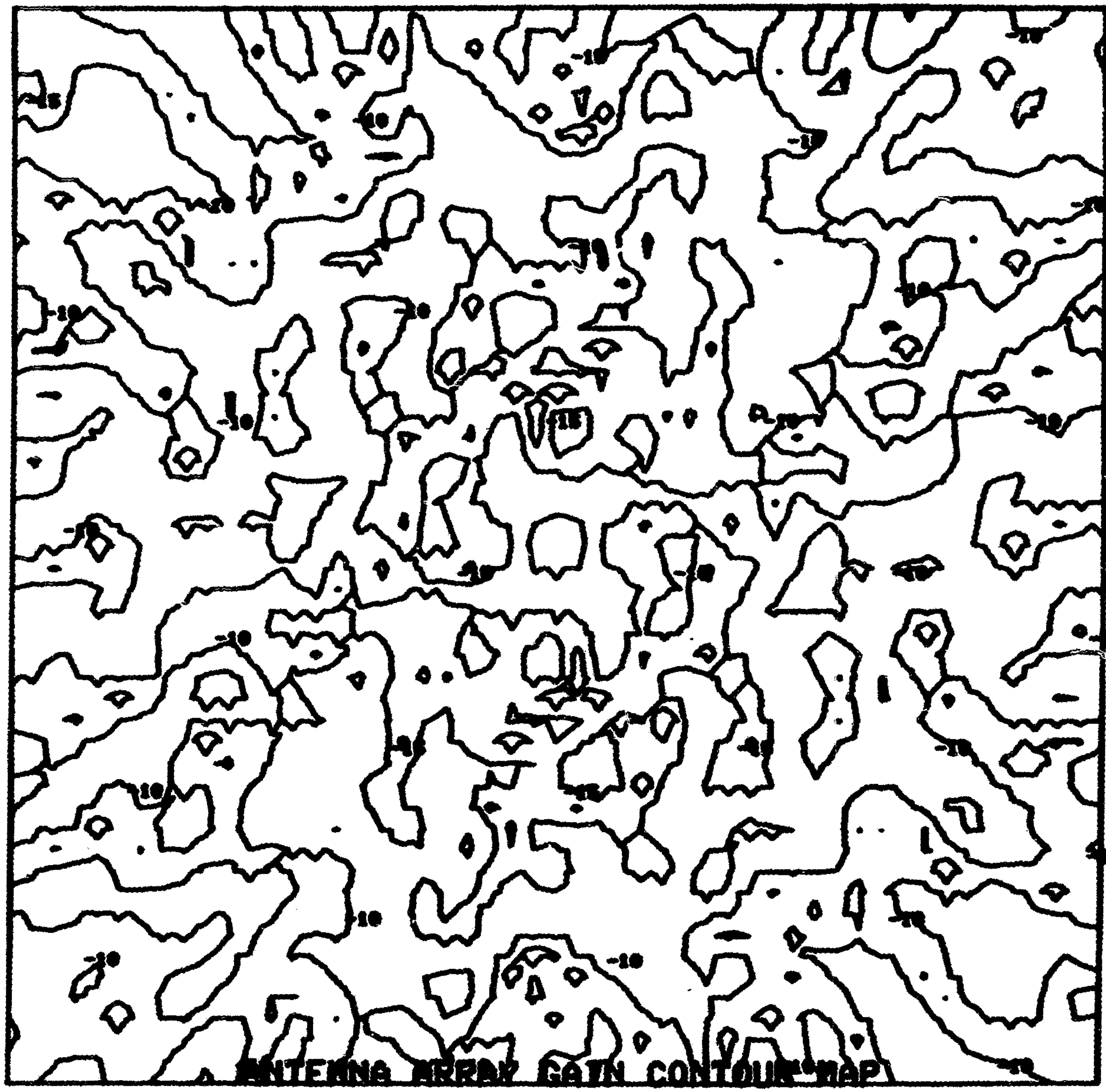
[illegible] 20.00 DEGREES
RESOLUTION= 50 X 50 SUBMAPS

GN&C UPDATE= 3.20 SEC

TAPE 07-DEC-81 18:33:17
TRACK BM A PKT 6. MO6 2
PACKET TIME 00:00:03
FREQ= 1646.825 MHZ

UTS #2 @ Boresight
Acquired No Interferer

Figure 5-28



PLOT DATA

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RADIUS= 60.00 DEGREES
RESOLUTION= 50 X 50 SUBMAPS

GMLC UPDATE= 53.80 SEC

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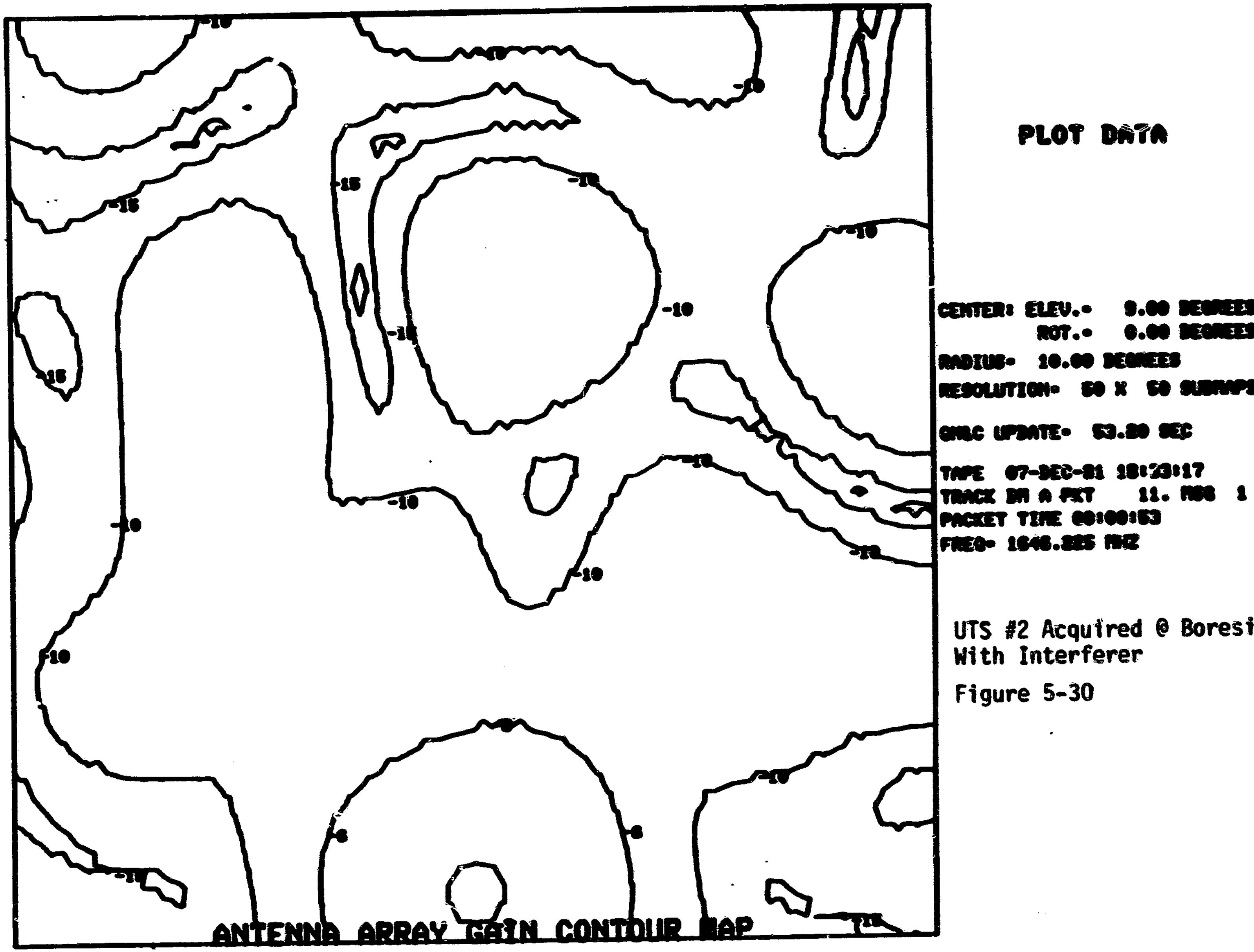
PACKET TIME 00:30:53
FREQ= 1646.825 MHZ

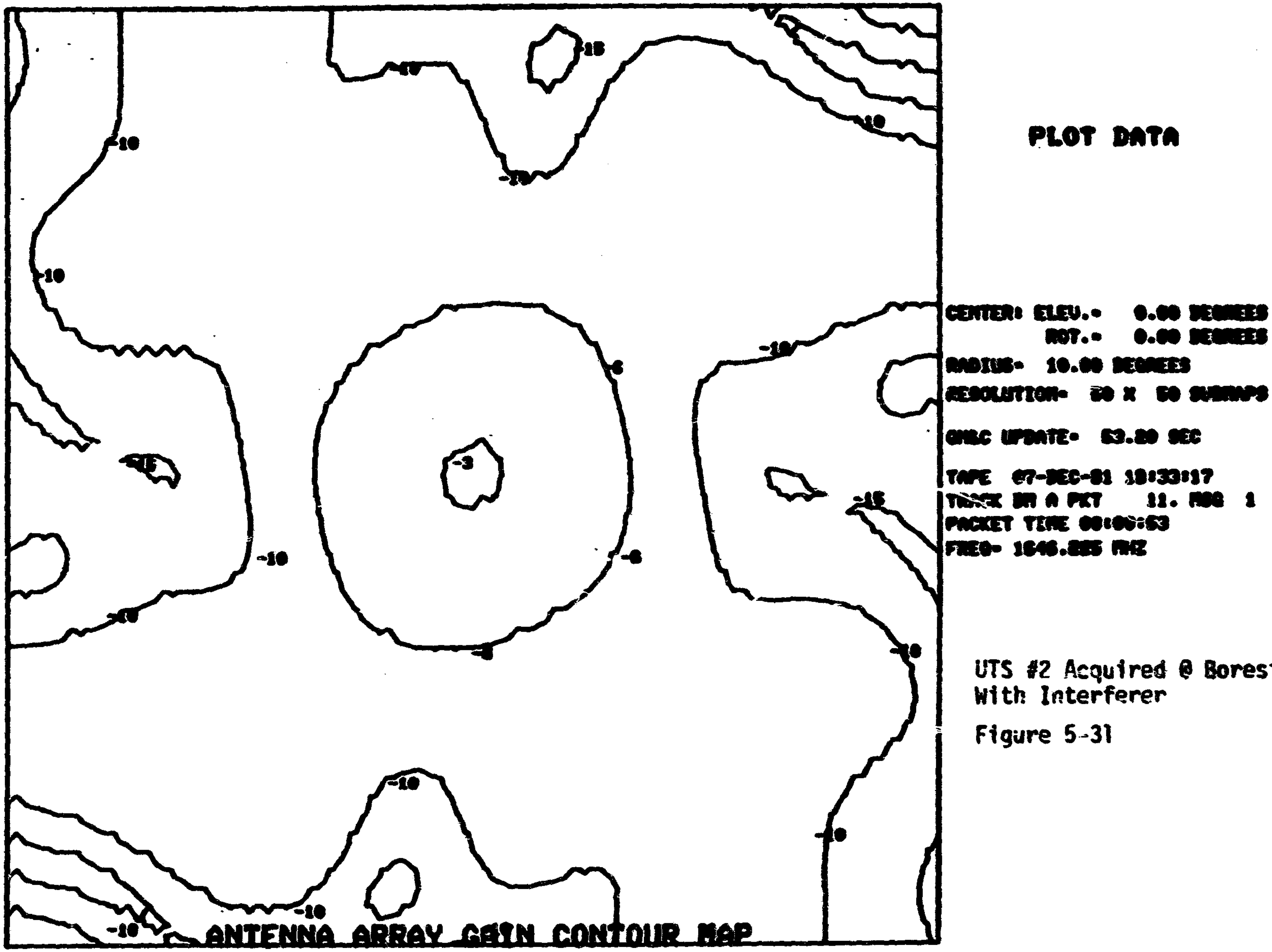
UTS #2 Acquired @ Boresight
With Interferer

Figure 5-29



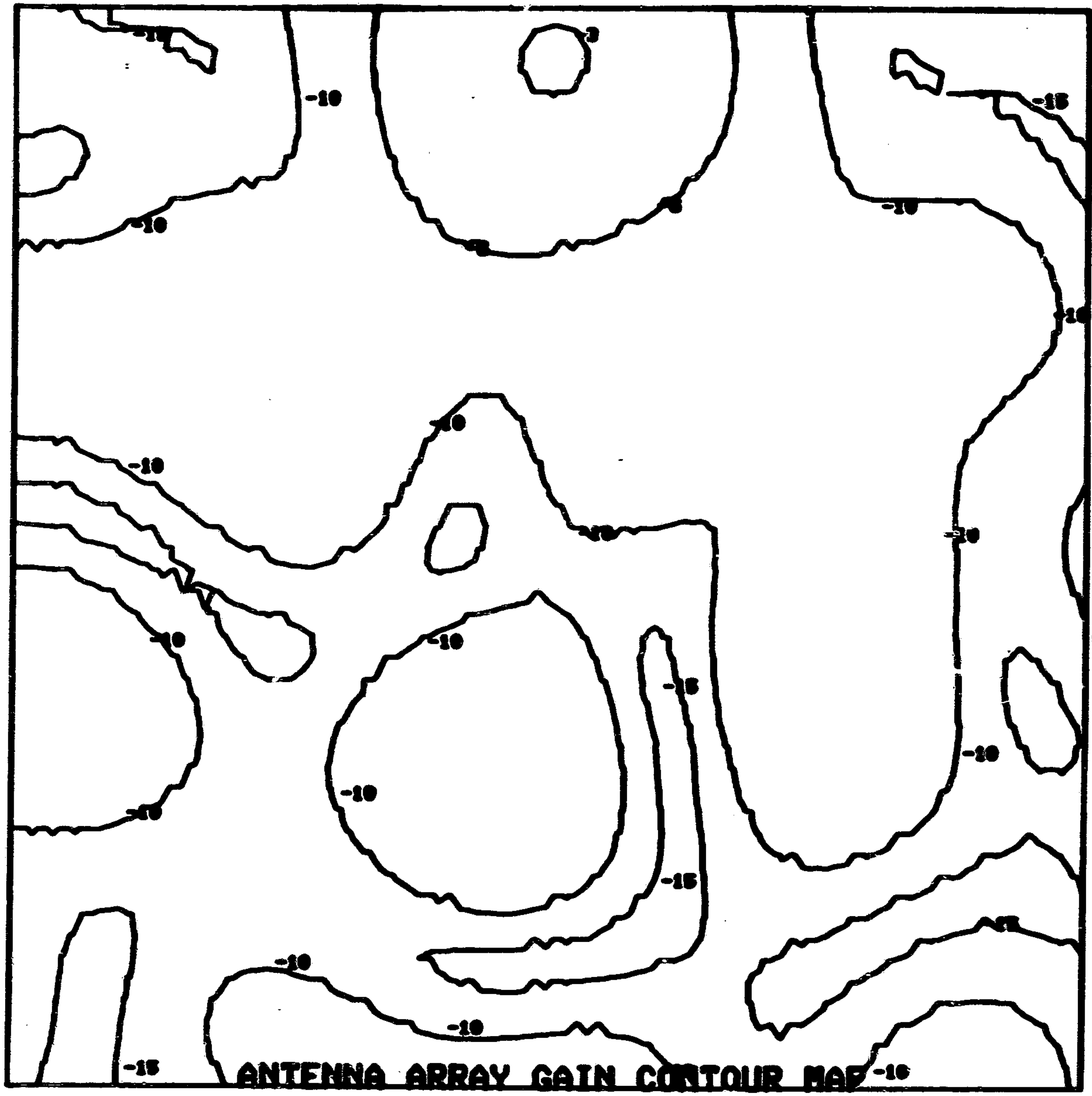
UTS #2 Acquired @ Boresight With Interferer

Figure 5-30



UTS #2 Acquired @ Boresight
With Interferer

Figure 5-31



PLOT DATA

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ROT.= 180.00 DEGREES
RADIUS= 10.00 DEGREES
RESOLUTION= 50 X 50 SUBMAPS

QMLC UPDATE= 53.80 SEC

TAPE 07-DEC-81 18:33:17
TRACK BM A PKT 11. MBG 1
PACKET TIME 00:00:53
FREQ= 1646.225 MHZ

UTS #2 Acquired @ Boresight
With Interferer

Figure 5-32

6.0 Results and Conclusions

The AMPA program has achieved most of the program goals that were established at the onset of the program. These goals can be summarized as follows:

1. Austere User Terminal Communications - By increasing the aperture (and hence gain) of the satellite relay antenna the requirements for User Terminal ERP and G/Ts are correspondingly decreased (dB for dB), thereby lowering the cost and size of the User Terminals. In order to provide full earth disc coverage, multiple higher gain beams are required inasmuch as the higher gain results in beamwidths that cover only a fraction of the field of view. The AMPA program has demonstrated that:

- Higher gain receive and transmit beams can be generated,
- They can be pointed anywhere in the field of view,
- A signal of unknown apriori location can be acquired on the basis of a distinguishing code,
- Signals can be tracked in the face of relative angular motion between the satellite and the User Terminal
- Multiple simultaneous beams can be generated by a common set of elements without mutual interference.

2. <u>Frequency Reuse</u> - The limited available microwave spectrum cannot accomodate all the potential users of satellite communications relay. This is especially true for potential maritime and aeronautical communications and data collection in the L-band allocation. As the array technology exemplified by AMPA reduces User Terminal costs, it will increase the number of potential users who will find it economical to use the service. AMPA has demonstrated that:

- Multiple simultaneous receive and transmit beams operating on the same frequency can multiply the number of communications links that can be operated on a single frequency channel without mutual interference.

3. <u>Communications in the Face of Interference</u> - As User Terminals with smaller ERP's are able to be accomodated by the higher gain satellite antennas exemplified by AMPA, the likelihood that the signal will be interfered with by a co-channel emission is increased. AMPA has demonstrated that:

- Communications can be established and maintained in the face of interfering co-channel signals.
- The interfering signal can be much stronger than the intended communications signal and still "nulled" by AMPA.
- Neither the location of the desired signal or the interferer needs to be known apriori in order for the AMPA system to provide communications in the face of co-channel interference.

4. Geolocation - For the purposes of data collection and search and rescue applications, it is desirable to provide rough geolocation of signal sources. Two techniques were proposed at the onset of the AMPA program:

- Scanning in discrete cells with interpolation.
- Multiple baseline interferometry

During the course of the AMPA program, the software for these techniques was written and simulations were run. Test demonstrations of scanning in discrete cells was accomplished and formed the basis of the acquisition process.

5. Intermodulation Dispersion - Communications Satellite DC power requirements are driven primarily by the transmit amplifiers. Saturated amplifiers (Class C) are more efficient than their linear cousins and hence, require less DC power for the same RF output. However, saturated amplifiers generate intermodulation products that can severly degrade the signal to noise ratio received at the user terminals. Phased arrays have the property that they tend to spatially disperse these intermodulation products because the products are higher order phenomena that are not "phased up" when the primary beams are formed. Test demonstrations of this characteristic were not conducted in the AMPA program.

6.1 Limitations

The AMPA program underwent several changes during the development phase. Originally, it was intended that AMPA would fly on SPACE LAB with its attendant emphasis on flight qualified hardware and the need for autonomous System Test Equipment.

A reassessment of AMPA as a flight experiment, coupled with the slippage of Shuttle and the reduction of flights, prompted a redirection of AMPA to a ground test program.

When the program ran into delays and consequent overruns, adequate funds could not be found to complete the program as planned. As a result, some problems were identified but not repaired and tests that were originally planned were not run so as to make optimum use of the available funds. Items that fell into this category include:

- Noise Figure of the User Terminals - The front end mixers of the user terminals (WJ-MIK) require +17 dBm LO drive to achieve their rated noise figure. The actual LO drive was 0 dBm resulting in a noise figure increase of approximately 20 dB.

- Transmitted CNR of the User Terminal - Although the ERP of the user terminals exceeded the specification, the carrier to noise ratio of the transmitted signal was degraded by the same WJ-MIK mixer used with inadequate LO drive in the final up converter.

- Variation in Element Gains, Noise Figures and ERPS - Theoretically, all elements, receivers and transmitters have identical gains, noise figures, and ERP's. In practice, there is some variation. This can be calibrated and accounted for in the adaptive processes on both reception and transmission. In the AMPA program with 32 elements and a very non-benign environment (on the roof at Melville, Long Island for over a year) the variations increased with time. When funds had to be optimally allocated, it was decided not to repair failed elements (2 on receive, 5 on transmit) and to work around variations in gain of the operating elements.

- Transmit Nulling Software - Providing transmit gain towards a desired user terminal while simultaneously generating a null in the direction of another user terminal is primarily a calibration and a solid geometry software problem that bypasses most of AMPA's hardware. This software was written, debugged and demonstrated in simulation. At the very end of the AMPA test phase, there was only time to try a live demonstration once. It did not work. It is the belief of the personnel involved that a simple algorithmic interface not tested by the simulation was the probable cause.

6.2 Conclusion

The Adaptive Multibeam Phased Array (AMPA) program was conducted to demonstrate the satellite communications advantages of Adaptive Phased Array Technology.

While sufficient funds to complete the program could not be found, the available funds were allocated to provide maximum demonstration of key program objectives.

The AMPA program did demonstrate:

- Communications with Austere User Terminals
- Frequency Reuse
- Communications in the Face of Interference
- Geolocation

It can be concluded from these demonstrations that Adaptive Phased Array Technology using tens of elements that each cover the field of view can provide:

- Significant antenna gain increase over that which covers the field of view . . . . AMPA demonstrated approximately 15 dB.
- Multiple simultaneous independently steerable beams that each cover the entire field of view . . . . AMPA demonstrated 2 each - receive and transmit beams.
- Communications in the face of substantially stronger co-channel interference . . . . AMPA demonstrated over 35 dB of signal to interference plus noise ratio improvement.

- Acquisition of desired user terminal signals with and without a priori knowledge of user terminal location . . . . AMPA demonstrated acquisition based on known angle of arrival, on known latitude and longitude and on a known PN code.
- Expanded use of a limited frequency allocation by providing simultaneous use of common channels without mutual interference . . . . AMPA demonstrated two simultaneous channels sharing a common frequency.

In addition, the AMPA program established the viability of both the hardware and software required for the implementation of adaptive phased array technology for satellite communications applications.

The next step in the development process would be flight testing of a development model on board a suitable platform.

Appendix A

S-420-2(A)

PERFORMANCE SPECIFICATION

FOR THE

ADAPTIVE MULTIBEAM PHASED ARRAY

(AMPA)

EXPERIMENTAL COMMUNICATIONS SYSTEM

December 1979

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

PERFORMANCE SPECIFICATION

FOR THE

ADAPTIVE MULTIBEAM PHASED ARRAY

(AMPA)

EXPERIMENTAL COMMUNICATIONS SYSTEM

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GODDARD SPACE FLIGHT CENTER
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NOTICE

This specification is a comprehensive revision of GSFC Specification S-420-2, "Performance Specification for the Adaptive Multibeam Phased Array (AMPA) Instrument for Spacelab," dated October 20, 1977. The specification revision reflects a direction* from the Office of Space and Terrestial Applications, NASA Headquarters, to cancel AMPA as an instrument development for flight on Shuttle/Spacelab but continue the program as a laboratory model experiment development to be tested in place at the contractor's facility, AIL Division of Eaton Corporation, Melville, New York.

*Letter from E/Associate Administrator for Space and Terrestial Applications to Director, GSFC, dated June 25, 1979, re: redirection AMPA project as a nonflight laboratory experiment.

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CONTENTS (Continued)

ILLUSTRATIONS

TABLES

ACRONYMS

AMPA	Adaptive Multibeam Phased Array
CRT	Cathode-ray tube
C/No	Received signal power to noise power density ratio
DEP	Dedicated experiment processor
EIRP	Effective isotropic radiated power
EPET	Electrical performance evaluation test
FM	Frequency modulation
FOV	Field of view
G/T	Receiving system antenna gain to noise temperature ratio
HPBW	Half-power beamwidth
IF	Intermediate frequency
LHCP	Left-hand circular polarization
NRZ-L	Nonreturn to zero level
PSK	Phase-shift keying
RF	Radio frequency
STE	Special test equipment

PERFORMANCE SPECIFICATION
FOR THE
ADAPTIVE MULTIBEAM PHASED ARRAY
(AMPA)
EXPERIMENTAL COMMUNICATIONS SYSTEM

1. SCOPE

This specification defines the performance and operational requirements of the Adaptive Multibeam Phased Array (AMPA) Experimental Communications System. The AMPA system consists of a laboratory experimental model, special test equipment (STE), including user terminal simulators, and associated software and documentation.

2. APPLICABLE DOCUMENTS

The following documents of the date of issue stated contain reference data and information that may be used as a guide in the design, development, and test of the AMPA system:

a. STS Accommodation Study for the AMPA Antenna System, Final Report, Contract NAS5-23411, General Electric Space Division, March 1979.

b. STDN No. 108 PN Codes for Use with the Tracking and Data Relay Satellite System, NASA/GSFC, December 1976.

c. Adaptive Multibeam Antennas for Spacelab - Phase A Feasibility Study, Final Report, Contract NAS 5-22425, February 1976 (prepared by General Electric, STAR Accession No. N-76-304-47).

d. Adaptive Multibeam Phased Array Design for a Spacelab Experiment, Final Report, Contract No. NAS 5-23469, March 1977 (prepared by AIL, a division of Cutler-Hammer, STAR Accession No. N-77-201-50).

3. EXPERIMENTAL MODEL REQUIREMENTS

The AMPA Experimental Model is the simulated spaceborne segment of an advanced communications system which would be flown on an Earth-viewing polar-orbiting low-altitude satellite. The Experimental Model, as defined for this specification, shall include all simulated spaceborne antennas, receivers, transmitters, signal processing, and data-processing subsystems required for meeting the functional specifications stated in this document. The Experimental Model shall consist of two subsystems (i.e., array and module).

The AMPA operations program will include demonstration and evaluation of the Experimental Model performance in radio-frequency (RF) communications links to cooperating user terminal simulators in the several modes of system operation.

3.1 INSTRUMENT FUNCTIONAL REQUIREMENTS

3.1.1 Point-to-Point Communications

3.1.1.1 General Communications Functions—The AMPA Experimental Model shall be capable of supporting communications links to user terminals that meet the RF parameters given in Table 1.

The AMPA Experimental Model shall utilize an antenna array to simultaneously form two receive beams and two transmit beams, each of which is independently steerable. In the absence of interfering signals, the signal-to-noise ratios in Table 1 should be maintained for user terminal to user terminal relay communications, for communications from a user terminal to Experimental Model receiver outputs, and for Experimental Model Transmitter inputs to a user terminal.

3.1.1.2 Simplex Receive Mode—The AMPA Experimental Model shall be capable of operating in a simplex receive mode in which signals may be received simultaneously from two different user terminals transmitting in conformance with the frequency plan of Table 1. These signals shall be demodulated and provided as output data to be processed.

Table 1
AMPA User-Terminal Characteristics

Parameter	Value (nominal)
G/T (minimum)	-30 dB/K
EIRP (minimum)	+10 dBW
C/N_0 (minimum)	+53 dB-Hz
Polarization (transmit and receive)	LHCP
Antenna beam pattern/FOV	Hemispheric
Axial ratio	4 dB
Receive frequencies (nominal)	Channel A 1544.725 MHz Channel B 1544.775 MHz
Transmit frequencies (nominal)	Channel A 1646.225 MHz Channel B 1646.275 MHz

3.1.1.3 Simplex Transmit Mode—The AMPA Experimental Model shall be capable of operating in a simplex transmit mode that shall permit transmissions to two different user terminals simultaneously in conformance with the frequency plan of Table 1. The modulation inputs for these transmissions shall be accepted from an external output.

3.1.1.4 Simplex Receive/Transmit Mode—A simplex receive/transmit mode shall be incorporated into the AMPA Experimental Model which shall consist of simultaneous operation of the simplex receive mode specified in paragraph 3.1.1.2 and the simplex transmit mode specified in paragraph 3.1.1.3. This mode shall allow signals to be received from two user terminals, with simultaneous transmission to user receivers at two other user locations. Received signals shall be processed and/or routed to a transmitter modulator.

The transmitter inputs shall be derived from either external modulation inputs or modulation from demodulated received signals from the ground terminals.

3.1.1.5 Full Duplex Mode—The AMPA Experimental Model shall be capable of operating in a full duplex mode that shall allow duplex communications with two user terminals. A received signal from one user terminal shall be demodulated and routed either to the system output, to the modulator of the transmit beam, to the second user terminal, or to both. Transmit modulator inputs shall be either from the external source or from demodulated received signals. This signal routing shall allow duplex communications between two user terminals.

3.1.1.6 "Bent Pipe" Mode—The AMPA Experimental Model shall be capable of operating in a bent pipe mode that shall allow reception of data from one user terminal and retransmission to another without demodulation. The bent pipe mode shall allow intermediate frequency (IF) translation from the received IF to the transmit IF bypassing the modulation/demodulation functions for communications between two user terminals. This mode shall allow simultaneous transmission and reception at both user terminals. In addition to the frequency translation, received signals shall be demodulated to allow monitoring of data quality for experimental purposes. The bent pipe mode retransmission 3-dB bandwidth shall be a minimum of 2.5 MHz centered about the nominal AMPA system operating frequencies of Table 1.

3.1.2 Beam Pointing and Shaping Functions

3.1.2.1 Static Programmed Pointing Mode—Both transmit and receive beams of the AMPA Experimental Model shall be steerable by a static programmed pointing mode that shall allow all beams to be independently pointed in any direction in the system field of view. The beams shall be pointed by real-time or stored commands (azimuth or elevation angle data relative to the nadir). In this mode, the beams shall remain pointed in fixed directions with respect to the AMPA antenna nadir until commanded otherwise. This mode may be mixed with other modes to allow open-loop pointing of a particular beam while other beams are pointed in other modes. In this mode, the antenna shall operate as a standard phased array without adaptive mainbeam or sidelobe control. Communications modes for this pointing mode are specified in the first column of Table 2. Maximum beam pointing update rate shall be once per 10 seconds.

Table 2
AMPA Communications Modes Versus Pointing Modes
for Transmit (T) and Receive (R)

	Pointing Modes					
	Static Programmed		Dynamic Programmed		Adaptive	
Communications Modes	R	T	R	T	R	T
Simplex receive	X		X		X	
Simplex transmit		X		X		X
Simplex receive/transmit	X	X	X	X	X	X
Full duplex	X	X	X	X	X	X
Bent Pipe	X	X	X	X	X	X

3.1.2.2 Dynamic Programmed Pointing Mode—The AMPA Experimental Model shall be capable of pointing both receive and transmit beams by a dynamic programmed pointing mode. This mode shall allow each beam to be pointed to a given ground point, specified by ground-location longitude and latitude data and simulated host satellite ephemeris and attitude data. If a specified point is not within the field of view at a particular time, a beam being pointed by this mode shall be steered to the horizon point at which acquisition is anticipated. Commands for this mode may be issued from the STE keyboard or the set of stored commands. Commands from the AMPA control system shall control transmit beam pointing when receiver beams are pointed by the adaptive mode specified in paragraph 3.1.2.3. As in 3.1.2.1, the antenna shall operate as a standard phased array without adaptive mainbeam or sidelobe controls. Beam steering control shall utilize simulated host satellite ephemeris and attitude state data to maintain required beam pointing accuracy. The communications modes specified in the middle column of Table 2 shall be available for the dynamic programmed pointing mode. Maximum beam pointing rate shall be once per 10 seconds.

3.1.2.3 Adaptive Pointing and Beam Shaping Mode—The AMPA Experimental Model shall be capable of beam pointing and beam shaping by an adaptive mode. This mode shall allow the Experimental Model to acquire and beam-track transmissions from user terminals, suppress interfering signals, and form transmit-beam nulls in specified directions.

a. Receive-Beam Acquisition and Track—The Experimental Model shall be capable of automatically acquiring and beam tracking transmissions from either of two cooperating AMPA user terminals. The received signals may be of different or of the same frequencies, but shall be identifiable by unique signal-address codes. The Experimental Model shall have a priori knowledge of user address codes and frequency, but not of user terminal locations or scheduled times of signal contact.

b. Receive Beam Shaping and Suppression of Interfering Signals—The Experimental Model shall be capable of suppressing cochannel interfering signals by automatically forming receive-pattern nulls in the direction of the interfering source. Interfering signals shall be of constant-power type, but may be of arbitrary modulation and spectral characteristics.

c. Transmit Beam Shaping and Interbeam Isolation—Adaptive mode transmit-beam pointing shall be on the basis of angle information accepted from the receiving system beam-control networks or from externally supplied angle information as in 3.1.2.1 and 3.1.2.2. In either case, the Experimental Model shall be capable of forming a minimum of one transmit null per transmit beam in a command-specified direction that is within the field of view but not closer than one-half beamwidth of the desired transmit-beam center. Under conditions of dual transmit-beam operation at the same frequency, interbeam isolation shall be maintained by forming a null of beam 1 in the direction of beam 2 and vice versa.

3.1.2.4 Beam Pointing and Beam Shaping Performance Criteria—In the programmed modes of paragraphs 3.1.2.1 and 3.1.2.2, beam pointing accuracy shall be within ±0.5 degrees of the commanded angle at time of update. In the adaptive receive modes of 3.1.2.3a and 3.1.2.3b, beam pointing and shaping shall be on the criteria of maximizing received user signal to noise or noise-plus-interference. Interfering signals shall be assumed to be left-hand circular polarization (LHCP). In the adaptive transmit mode of 3.1.2.3c, beam pointing and shaping shall be on the basis of minimizing Experimental Mode effective isotopic radiated power (EIRP) in the command-specified direction consistent with a maximum EIRP degradation of 2.0-dB, the desired beam center. The 2.0-dB degradation criterion shall apply only when the null to desired signal separation is greater than or equal to the half-power beamwidth (HPBW). The design goal for transmit-beam null depth is 20-dB ±60 degrees over the Experimental Model field of view, excluding conditions in which the null-to-desired signal separation is less than the HPBW.

3.1.3 Geolocation

In the adaptive receive mode, the Experimental Model shall be capable of estimating the apparent position, in latitude and longitude coordinates, of simulated AMPA user terminals in the RF scenario. Design-goal root sum square geolocation (coarse case) accuracy shall be not less than ±2.0-degrees (array elevation and azimuth coordinates) over the ±60-degree FOV. With additional processing (fine case), design-goal accuracy shall be increased to ±0.1-degree. Data-processing and related software shall be provided for transforming estimated geolocation elevation and azimuth-angle data to Earth-surface latitude and longitude, utilizing simulated ephemeris and attitude data for a host satellite in a circular polar orbit at an altitude of 870 km. These specifications apply under the clear channel and interference environments specified in paragraphs 3.2.5.2a and 3.2.5.2b.

3.2 EXPERIMENTAL MODEL PERFORMANCE REQUIREMENTS

3.2.1 Antenna Array Subsystem

3.2.1.1 Array Geometry—The AMPA antenna-array subsystem shall be configured in accordance with AIL drawing 563453 (Array Subsystem Assembly Drawing). The array structure shall be

compatible with the mounting interface criteria of drawing 47D252766 of Applicable Document 2.1.1.

3.2.1.2 Frequencies of Operation—The antenna array shall be designed to operate over the frequency range 1.5 to 1.7 GHz with a nominal receive frequency of 1.646 GHz and a nominal transmit frequency of 1.544 GHz.

3.2.1.3 Field of View—The overall field of view (FOV) shall be in the form of a cone with an included angle of not less than 120 degrees where the axis of the cone is the antenna-array boresight direction.

3.2.1.4 Beamwidth—The array shall have a basic capability of forming beams of not more than 5 degrees on-axis. Off-axis HPBW may have an approximate cosine dependence and shall not exceed 15 degrees over the FOV.

3.2.1.5 Polarization—The polarization of the array elements shall be left-hand circular for both receive and transmit where the axial ratio is less than 3-dB for the FOV and beamwidth given in paragraphs 3.2.1.3 and 3.2.1.4, respectively.

3.2.1.6 Array Elements—The antenna array shall incorporate a minimum of 32 antenna elements.

3.2.2 Receiving System

The receiving system shall consist of receiver elements that shall convert the receive band to an IF frequency to be chosen by the contractor.

3.2.2.1 Number of Receiver Elements—The number of receiver elements shall equal the number of antenna elements. The output of each receiver element shall be routed by IF transmission line from the array to the receiver processor subsystem. Receive-beam forming shall be performed at IF.

3.2.2.2 Bandwidth—The reciever bandwidth shall be 2.5 MHz centered about the nominal center frequency.

3.2.2.3 Sensitivity—The receiving system sensitivity shall be adequate to meet minimum system carrier-to-noise density criteria of Table 1 in all links of AMPA user terminals. System parameters may be scaled in the RF scenario with user-terminal simulators for the Experimental Model test program. Scaled parameters shall reflect link conditions for an 870-km-altitude orbit and the specified field of view.

3.2.2.4 Dynamic Range—The receiver dynamic range shall be scaled to simulate the system carrier-to-noise density requirements specified in paragraph 3.2.2.3 in the presence of any ground transmission having an EIRP 40-dB greater than that specified in Table 1 and located at nadir.

3.2.2.5 Maximum Input Signal—The Experimental Model shall not be damaged by signals with a power of 1 mW at any element.

3.2.3 Transmitting System

The transmitting system shall consist of elements located at the array that convert IF inputs to RF signals with the appropriate power for meeting overall system signal-to-noise ratio requirements for each of two transmit beams (Table 1). The IF signals shall originate from the signal-processing subsystem in which transmit-beam formation shall be performed.

3.2.3.1 Number of Elements—The number of transmitter elements shall equal the number of antenna elements. Each element shall have a different input at IF.

3.2.3.2 Power Amplifier Characteristics—The transmitter elements shall emulate linear operation with one or two equal power RF carriers. Simulated Experimental Model EIRP requirements per beam that provide Table 1 carrier-to-noise densities shall be met under two signal conditions. RF parameters shall be scaled to reflect link conditions for an 870-km-altitude orbit and the specified field of view.

3.2.3.3 Bandwidth—The transmitter system bandwidth shall be 2.5 MHz centered about the nominal transmit frequency.

3.2.3.4 IF Interface—The transmitter system IF interface shall be at a frequency to be specified by the contractor. The interface shall be through a set of transmission lines, different from the receiver IF transmission lines, routed rom the module processor subsystems to the array subsystem.

3.2.4 Communications Signal Processing

3.2.4.1 Receive Signal Outputs—Outputs shall be provided from the beam forming networks corresponding to the two receive beams. These outputs shall be in a format that is compatible with the special test equipment interfaces. The signal processor shall be capable of demodulating analog voice communications and digital data and shall have capabilities for dynamic Doppler tracking for offsets as great as ±38 kHz.

a. Voice Communications—Two FM demodulators shall be provided for demodulating FM modulated voice signals with a peak deviation of up to 15 kHz. In the adaptive receive mode, specified in paragraph 3.2.4.1c, the system shall be capable of demodulating the AMPA adaptive mode signal structure.

b. Digital Data—Two digital detectors shall be provided for demodulating signals when the carrier is PSK-modulated with nonreturn to zero-level (NRZ-L) format data at a selectable bit rate of 1.0×2^N kbps, where N is an integer in the range $0 \leqslant N \leqslant 5$. In addition, the capability shall be provided on one channel for detecting errors in a 2047-bit pseudo-random code to provide a measure of the bit-error rate. Bit-error rates in the range 1 error in 10^5 bits to 1 error in 10 bits shall be measured.

c. Signal Design for Adaptive Mode—The structure of signals received by the Experimental Model when operating in the adaptive mode specified in paragraph 3.1.2.3 will allow

identification of users by a unique code that shall allow the adaptive processor to recognize desired signals for beam pointing and interferers for null pointing. This structure will have orthogonal properties to allow a minimum of 10-dB rejection of two such signals with overlapping spectra and will have provisions for a unique address for each user. The signal design for the adaptive mode will allow compatibility with data transmission rates between 1 and 32 kbps.

3.2.4.2 Transmit Input Signals—Input signals for the simplex transmit mode shall be provided from and external source.

a. Frequency Plan and Channelization—The capability shall be provided for forming transmit beams at the nominal transmit frequencies of Table 1. Beams may be at the same or different frequencies and may be directed anywhere in the field of view. Modulation capability shall be provided as specified in paragraphs 3.2.4.2b and 3.2.4.2c.

b. Voice Communications Mode—Provisions shall be incorporated for voice modulation of the channels as FM with a peak deviation up to 15 kHz.

c. Digital Communications Mode—Provisions shall be incorporated for PSK modulation of the channels with NRZ-L data at bit rates between 1 and 32 kbps. Two 2047-bit pseudo-random code generators shall be provided for input to the channels in the digital communications mode.

3.2.4.3 Repeater Mode—An operating mode shall be provided by which the receive IF output and the transmit IF input can be connected for retransmission of received signals.

a. Frequency Plan and Channelization—It shall be possible to directly connect the receive system IF output to the transmitting system IF input, making the full 2.5-MHz bandwidth available for retransmission. Channel-to-channel connection shall also be possible by which either receive channel can be retransmitted at either transmit channel. Retransmission signal sense of modulation shall be the same as that of the receive signal.

b. Transfer Characteristics—The transfer characteristics in the repeater mode shall reflect the receiving system requirements specified in paragraph 3.2.2 and the transmitting system requirements specified in paragraph 3.2.3.

3.2.5. Beam Control

3.2.5.1 Nonadaptive Beam Control—Nonadaptive beam control shall be utilized in the programmed pointing modes specified in paragraphs 3.1.2.1 and 3.1.2.2 for both receive and transmit beams. This type of beam control shall consist of mainlobe beam pointing only and shall not include beam shaping and null pointing. Nonadaptive beam control shall maintain the gain of sidelobes (excluding grating lobes) a minimum of 10 dB below the main lobe gain over the field of view.

3.2.5.2 Adaptive Beam Control—Adaptive beam control shall be provided only on receive and transmit modes as specified in paragraph 3.1.2.3. This type of beam control shall provide receive signal acquisition and dynamic mainlobe beam steering and shaping and null steering.

a. Clear-Channel Environment—Maximum receive-signal acquisition time in a clear-channel environment shall be 7.5 seconds. A clear-channel environment shall be defined as a condition in which there are no interfering signals within the FOV of the Experimental Model producing cochannel EIRP greater than that of Table 1. Under this condition, the Experimental Model shall acquire and track up to two cooperating users anywhere within the field of view of the Experimental Model.

b. Interference Environment—Maximum acquisition time in an interference environment shall be 10 seconds. An interference environment shall be defined as a condition in which an interfering signal exists within the FOV of the Experimental Model, producing cochannel EIRP up to 30 dB greater than that of Table 1. Under this condition, the Experimental Model shall acquire and track up to two cooperating users anywhere in the field of view, except within one-half beamwidth of the interfering sources.

c. Transmit Beam Shaping—The performance criteria of paragraph 3.1.2.4 shall be met under both static and dynamic programmed modes, as well as under the mode in which transmit-beam pointing data are derived from the receiving system operating in an adaptive tracking mode. (See paragraph 3.1.2.3c.)

4. GROUND EXPERIMENT TEST PROGRAM

4.1 GENERAL

4.1.1 Test Program Objectives

The primary objectives of the AMPA Experimental Model test program are to verify performance. A minimum-cost approach is desired.

4.2 ELECTRICAL PERFORMANCE EVALUATION TEST

A complete end-to-end electrical performance evaluation test (EPET) of the fully assembled Experimental Model shall be performed to baseline system electrical parameters and shall demonstrate conformance with the performance requirements of paragraph 3.2 of this Specification. This test shall be run at ambient pressure and temperature. Simulated RF-signal sources shall be used to test instrument sensitivity and dynamic range over the specified ranges of frequency and signal level in all operating modes. Test facility requirements are detailed in paragraph 7.2.

Elements of the EPET may be satisfied by analysis and/or prior test data as per contractor's approved test plan.

5. PRODUCT ASSURANCE AND SAFETY

The AMPA experimental communications system contractor shall implement a product assurance program to ensure experiment success. The program shall encompass the following areas: reliability; programs and analyses; quality assurance, including manufacturing, inspection, and nonconformance controls; and safety. When applicable, existing contractor programs, procedures, and documentation shall be utilized.

6. CONFIGURATION MANAGEMENT

The contractor shall provide a configuration management (CM) system that defines the hardware by means of drawings, specification, etc. The contractor shall identify and define the Experimental Model and STE by means of drawings, specifications, procedures, plans, process control documents, parts/materials lists, and computer programs.

7. UNIQUE TEST FACILITIES AND SPECIAL TEST EQUIPMENT (STE)

7.1 GENERAL

The contractor shall provide all test facilities and STE required for supporting the Experimental Model assembly and test program performance and evaluations. The integrated complex of RF test facilitities and STE shall be capable of testing and evaluating all aspects of the Experimental Model operations, including RF and communications subsystem performance in all modes.

The contractor's STE design and implementation shall include a central computer, an RF scenario, and displays and controls as shown in Figure 1. A summary of STE computer software requirements and guidelines for implementation appear in Section 8.

7.2 RF TEST FACILITY

RF performance of the Experimental Model shall be evaluated and calibrated by a program of far-field antenna-array gain and pattern measurements. A suitably designed full-scale RF test facility shall be designed and implemented for quantitative evaluation of Experimental Model performance in the several modes of operation as detailed in paragraph 3.1. The scenario shall include CW radiated signal sources, simulated user terminals and interfaces, means for mapping and recording array pattern details in two dimensions over the ±60-degree circular FOV, and other elements as required.

Experimental Model RF performance parameters, including G/T, EIRP, beam shape, and axial ratio, shall be measureable to an absolute accuracy of ±0.5 dB over the ±60-degree FOV of the Experimental Model. Receiving system adaptive nulls shall be measurable to ±2.0 dB. Angular accuracy shall be 1°or better. The following items shall be considered in the design and implementation of the STE RF scenario:

- Far-field geometry criteria
- Use of Standard gain antennas and substitution techniques
- Field probing to verify plane-wave conditions
- Use of absorbent materials and structures to control reflections and multipath
- Use of rotating linear probes to measure axial ratio
- Normal ambient operating environment at the contractor's facility
- Federal Communications Commission authorizations for outdoor RF testing

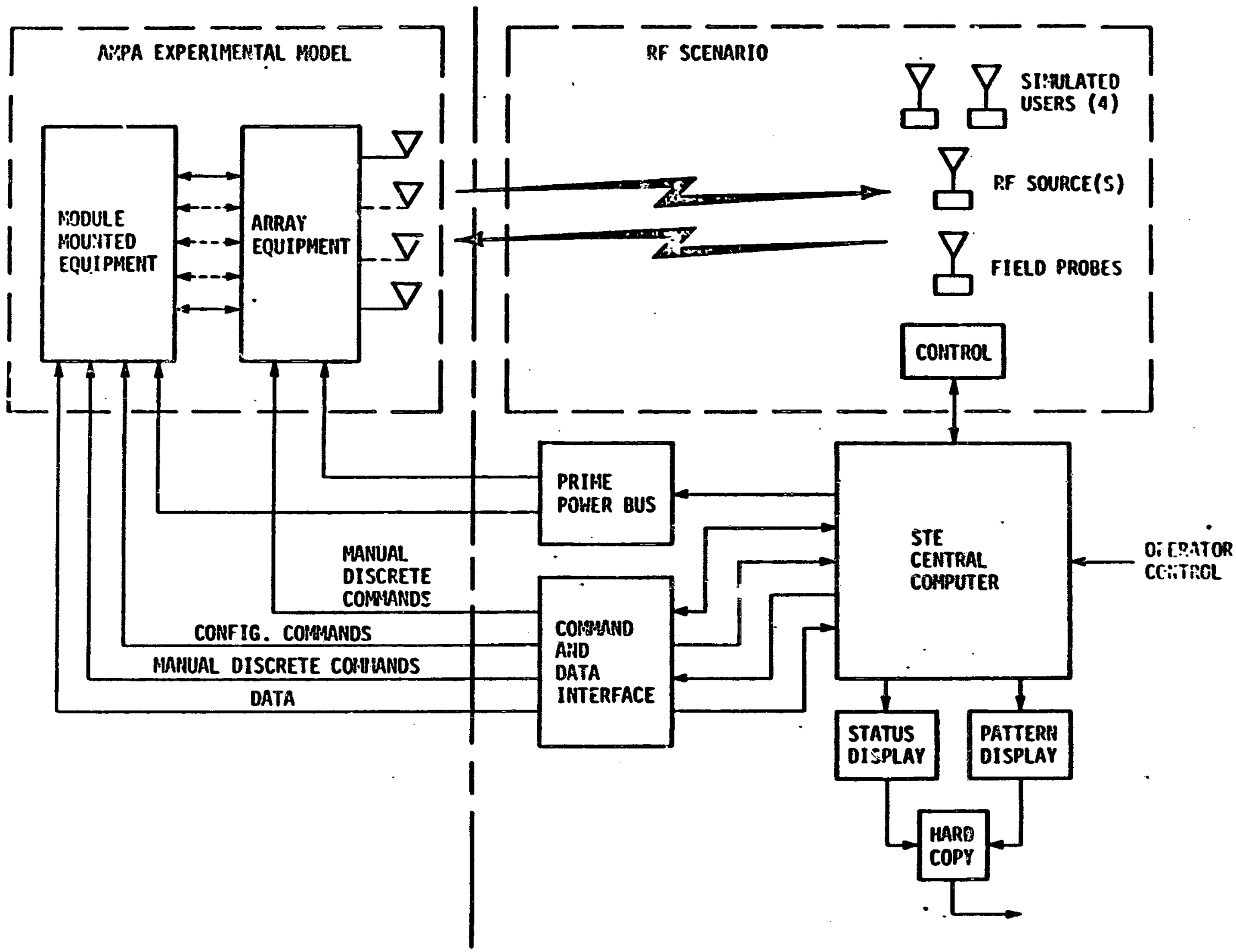

Figure 1. Suggested AMPA Test Complex Showing Principal Elements of STE

7.3 SPECIAL TEST EQUIPMENT

7.3.1 Command and Ancillary Data

The STE shall provide all required commands and ancillary data for operating and controlling the Experimental Model.

7.3.2 Data Processing and Display

The STE shall provide the capability for processing, displaying, and archiving and retrieving Experimental Model performance and status data.

7.3.2.1 Array Footprint Display–The STE shall include a CRT-type display of computed array-beam footprints or projections based on beam-forming network amplitude and phase states at a designated point in time from recorded Experimental Model output data.

a. Display Type–The display shall be of an X-Y type with minimum dimensions of 22 by 28 cm. As a minimum, the display shall include the computed 3-, 10-, and 20-dB contours for one of two designated beams over the Experimental Model projected FOV. The display shall include latitude and longitude values and other pertinent parameters.

b. Display Accuracy–Computed 3-dB contours shall be accurate to ±1.0-dB; 10- and 20-dB contours shall be accurate to ±2.0-dB. Factors to be considered in determining contour accuracy include uncertainties in array measurement and calibration in the RF scenario of paragraph 7.2; extrapolation of measured pattern data base to computed contours; and latitude longitude grid distortions.

c. Display Update–The STE shall be capable of generating a full X-Y display and updating the display for changes.

7.3.2.2 Status Display–The Experimental Model Status data shall be displayed and shall be updated at regular intervals.

7.3.2.3 Hardcopy Provisions–The STE shall include provisions for hardcopy of both the footprint display and the status display.

7.3.3 Power

The STE shall include a prime source for supporting and operating the Experimental Model during assembly and testing.

7.3.4 RF Scenario

The STE shall provide an RF scenario that simulates four AMPA user terminals and at least two interfering sources.

8. SOFTWARE REQUIREMENTS

The contractor's design shall include an instrument-internal dedicated experiment processor (DEP) and an STE computer. The DEP will support certain iterative computations associated with instrument-internal beam forming, pointing, and shaping functions. The STE computer will: (a) control overall system operations, (b) provide instrument data processing, archiving, and retrieval, (c) serve as supervisor/controller for the DEP, and (d) act as a host processor for instrument computational functions not performed in the DEP.

This section provides general guidelines with respect to system software design and establishes specific requirements in the areas of software development and documentation.

8.1 FUNCTIONAL SOFTWARE REQUIREMENTS

The contractor shall provide the necessary software for: (a) supporting the multiple functions associated with Experimental Model operation in the several operating modes, (b) controlling the Experimental Model, (c) emulating a host spacecraft, (d) estimating geolocations of user terminals transmitting to the Experimental Model, (e) otherwise meeting the requirements of Sections 3 and 7 of this specification. Specific software tasks may be located in the DEP, the STE, or both. In partitioning software functions between DEP and STE, consideration shall be given to the desirability of locating fixed iterative computational operations within the DEP. Software tasks that require external operator inputs, involve variable parameters, or involve operator control and intervention shall be resident exclusively in the STE.

8.2 GENERAL GUIDELINES

In developing the various elements of the software for the AMPA system, the contractor shall adhere to a system of structured programming that considers the following general guidelines:

- Programs modular in type and structure with restricted length, single entry/exit points, and avoidance of arbitrary transfer of controls (GOTO – less programming)
- Top-down development–definition of program structure at the highest level with successive decomposition into smaller and smaller tasks that are then converted into program modules
- Structured walkthrough–provisions for programming team reviews of both overall designs and actual codes
- Provisions for program verification, maintenance, and modification included in program definition
- Automatic test-case generation–generation of test data early in the development cycle by computer means

8.3 SPECIFIC GUIDELINES

The contractor shall adhere to the following specific guidelines relative to the specific computer or processor for which the software is to be provided.

8.3.1 Dedicated Experiment Processor

The software to be run on this computer may be written in machine language. The contractor shall supply any required operating system and loader software, as well as any software required for interfacing. Software development and maintenance shall be external to the DEP.

8.3.2 The STE Computer

The software to be run on this computer shall be written in a higher order language except when impractical and specifically waived by the Goddard Space Flight Center (GSFC). All STE software shall be provided in a system-compatible medium and shall be fully documented as specified in paragraph 8.4.

8.4 SOFTWARE DOCUMENTATION

All software supplied shall be documented by the contractor as a summary report. The software summary report shall consist of a description and listing of the programs. It should include a statement of the purpose of the software, the inputs he must supply, an indication of the inputs that are automatically provided (i.e., those he has no control over), and the outputs and/or action that result, including descriptions of error conditions that could be encountered. Examples of the inputs and outputs associated with the different software options should be included.

APPENDIX B

TEST DATA SHEETS

4.1 ANTENNA GAIN

TEST FREQUENCY - 1646 MHZ

	P_H	P_S	STANDARD GAIN	GAIN	SPECIFICATION
ANT # 1	-45 dBm	-46.5	14.9 dB	16.4	16DB, MIN
ANT # 2	-44.6 dBm	-46.5	↑	16.8	16DB, MIN
ANT # 3	-43.2 dBm	-46.5		18.2	16DB, MIN
ANT # 4	-45.3 dBm	-46.5		16.1	16 DB, MIN
INT A	-44.5 dBm	-46.5		16.9	16DB, MIN
INT B	-45.7 dBm	-46.5	↓	15.7	16DB, MIN
FIELD PROBE	-47 dBm		14.9 dB	17.5	16DB, MIN

TEST FREQUENCY 1544 MHZ

	P_H	P_S	STANDARD GAIN	GAIN (DB)	SPECIFICATION
ANT # 1	-44.8 dBm	-46.5	14.5 dB	16.2	16 DB, MIN
ANT # 2	-44.4 dBm	-46.5	↑	16.6	16 DB, MIN
ANT # 3	-43.2 dBm	-46.5		17.8	16DB, MIN
ANT # 4	-45.1 dBm	-46.5	↓	16.3	16DB, MIN
FIELD PROBE	-47 dBm	-46.5	14.5 dB	17.5	16 DB, MIN

TEST DATA SHEET

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4.2 RF Cable Insertion Loss

Cable	Power 1544.750 MHz		1646.250 MHz		
W1	-37.5	dBm	-40.0	dBm	(-40 dBm maximum)
W2	-37.5	dBm	-39.3	dBm	
W3	-36.9	dBm	-39.3	dBm	
W4	-37.2	dBm	-39.3	dBm	
W5	-37.2	dBm	-39.1	dBm	
W6	———		-38.8	dBm	
W7	———		-38.9	dBm	(-40 dBm maximum)

TEST DATA SHEET

U.T.S.

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5.1 G/T

Field Probe Sw. Position	Ant.	Gain	RF Cable	I.L.	a	F	Computed T_S	Computed G/T	Expected G/T
OFF	UTS #1	16.4 dB	W1	-40 dB	(10^{-4})	25 dB	49.62 dB/K	-33.22 dB/K	-15 dB/K min
ANT 1	F.P.	17.5	W2	-39.3	$1.17(10^{-4})$	26	50.62	-33.12	
OFF	UTS #2	16.8	W3	-39.3	$1.17(10^{-4})$	18.6	43.22	-26.42	
ANT 2	F.P.	17.5	W2	-39.3	$1.17(10^{-4})$	18.5	43.12	-25.62	
OFF	UTS #3	18.2	W4	-39.3	$1.17(10^{-4})$	28	52.61	-34.41	
ANT 3	F.P.	17.5	W2	-39.3	$1.17(10^{-4})$	28	52.62	-35.12	
OFF	UTS #4	16.1	W5	-39.1	$1.23(10^{-4})$	30	54.62	-38.52	
ANT 4	F.P.	17.5	W2	-39.3	$1.17(10^{-4})$	30	54.62	-37.12	-15 dB/K

Field Probe Sw. Position	Ant.	Computed G/T	G/T = -30 dB/K Computed Atten.	Measured G/T
OFF	UTS #1	-33.22 dB/K	dB	dB /K
ANT 1	F.P.	-33.12		
OFF	UTS #2	-26.42	3.6	
ANT 2	F.P.	-25.62	4.38	
OFF	UTS #3	-34.41		
ANT 3	F.P.	-35.12		
OFF	UTS #4	-38.52		
ANT 4	F.P.	-37.12		

$$G/T = G - 10 \log T_S \quad (dB/K)$$

where $T_S = 277\,a + 290\,(1-a) + 290\,(F-1) \quad (K)$

C-2

a) $T_s = a\ T_{ant} + T_o\ (1-a) + T_o\ (F-1)\quad (k)$

$=(10^{-4})\ (277) + 290\ (1-(10^{-4}) + 290\ (316-1)$

$=.0277 + 289.971 + 91,350$

$=91,639.99$

$=49.62$ dB $\qquad$ $G/T = 16.4 - 49.62 = -33.22$ dB/k

b) $T_s = a\ T_{ant} + T_o\ (1-a) + T_o\ (F-1)\quad (k)$

$= [1.17\ (10^{-4})]\ [277] + (290)\ [1 - 1.17\ (10^{-4})] + 290\ [398-1]$

$= 115,451 = 50.62 \qquad G/T = 17.5 - 50.62$

c) $T_s = a\ T_{ant} + T_o\ (1-a) + T_o\ (F-1)\quad (k)$

$= [1.17\ (10^{-4})]\ [277] + 290\ [1 - 1.17\ (10^{-4}) + 290\ [72.44 - 1]$

$= 21,008 = 43.22$

$16.8 - 43.22 = -26.42$

d) $T_s = a\ T_{ant} + T_o\ (1-a) + T_o\ (F-1)\quad (k)$

$= (1.17\ (10^{-4})\ (277) + T_o\ (1-1.17\ (10^{-4}) + 290\ (70.79-1)$

$= 20,530 = 43.12$ dB

$17.5 - 43.12 = -25.62$

e) $T_s = a\ T_{ant} + T_o\ (1-a) + T_o\ (F-1)\quad (k)$

$= [1.17\ (10^{-4})] + 277 + 290\ [1 - 1.17\ (10^{-4})] + 290\ (631 - 1)$

$= 182,687 = 52.61$

$18.2 - 52.61 = -34.41$

f) $T_s = a\, T_{ant} + T_o\,(1-a) + T_o\,(F-1)$ (k)

$= [1.17\,(10^{-4})](277) + 290\,[1 - 1.17\,(10^{-4})] + 290\,(631-1)$

$= 182999.99 = 52.62$

$G/T = 17.5 - 52.62 = -35.12$

g) $T_s = a\, T_{ant} + T_o\,(1 - a) + T_o\,(F - 1)$ (k)

$= [1.23\,(10^{-4})]\,(277) + 290\,[1 - 1.23\,(10^{-4})] + 290\,(1000 - 1)$

$= 289{,}999.99$

$= 54.62$ dB $G/T = 16.1 - 54.62 = -38.52$

h) $T_s = a\, T_{ant} + T_o\,(1-a) + T_o\,(F - 1)$

$= [1.17\,(10^{-4})]\,(277) + 290\,[1 - 1.17\,(10^{-4})] + 290\,(1000 - 1)$

$= 289{,}999.9985 = 54.62$ dB

TEST DATA SHEET

U.T.S.

6.1 EIRP

U.T.S. Configuration	EIRP
U.T.S. #1 ANT 1	-47 dBm (-46 dBm minimum)
U.T.S. #1 FIELD PROBE	-45.4 dBm (-48 dBm minimum)
U.T.S. #2 ANT 2	-45.5 dBm (-46 dBm minimum)
U.T.S. #2 FIELD PROBE	-44.5 dBm (-48 dBm minimum)
U.T.S. #3 ANT 3	-43.5 dBm (-46 dBm minimum)
U.T.S. #3 FIELD PROBE	-47 dBm (-48 dBm minimum)
U.T.S. #4 ANT 4	-46 dBm (-46 dBm minimum)
U.T.S. #4 FIELD PROBE	-46 dBm (-48 dBm minimum)

TEST DATA SHEET

U.T.S.

R/T-Control Unit Serial No. 001

6.2 CW Performance

"Channel 72" - J6	Frequency: 1646.2503 MHz (1646.250 MHz ± 500 Hz)	Power:* +17.5 dBm (+10 dBm minimum)
"Channel 51" - J6	Frequency: 1646.1841 MHz (1646.184375 MHz ± 500 Hz)	Power* +17.5 dBm (+10 dBm minimum)
"Channel 99" - J6	Frequency: 1646.3154 MHz (1646.315625 MHz ± 500 Hz)	Power* +17.5 dBm (+10 dBm minimum)

6.3 PN Code Generation

Code 1 - J6:	Power:	Record* 18.9 dBm (3 dB more than "Channel 99" power)
Code 2 - J6:	Power:	Record* 18.9 dBm (3 dB more than "Channel 99" power)

* Add 20 dB to measured values.

TEST DATA SHEET

U.T.S.

R/T Control Unit Serial No. 002

6.2 CW Performance

"Channel 72" - J9	Frequency: 1646.2502 MHz (1646.250 MHz ± 500 Hz)	Power: *+20.6 dBm (+10 dBm minimum)
"Channel 51" - J9	Frequency: 1646.1840 MHz (1646.184375 MHz ± 500 Hz)	Power: *+20.5 dBm (+10 dBm minimum)
"Channel 99" - J9	Frequency: 1646.3152 MHz (1646.315625 MHz ± 500 Hz)	Power: *+20.6 dBm (+10 dBm minimum)

6.3 PN Code Generation

Code 1 - J9: Power: Record* 22.1 dBm
(3 dB more than "Channel 99" power)

Code 2 - J9: Power: Record* 22.1 dBm
(3 dB more than "Channel 99" power)

* Add 20 dB to measured values

TEST DATA SHEET

U.T.S.

R/T Control Unit Serial No. 003

6.2 CW Performance

"Channel 72" - J11	Frequency: 1646.2496 MHz (1646.250 MHz ± 500 Hz)	Power: * +15.84 dBm (+10 dBm minimum)
"Channel 51" - J11	Frequency: 1646.1838 MHz (1646.184375 MHz ± 500 Hz)	Power* +15.84 dBm (+10 dBm minimum)
"Channel 99" - J11	Frequency: 1646.31526 MHz (1646.315625 MHz ± 500 Hz)	Power* +15.84 dBm (+10 dBm minimum)

6.3 PN Code Generation

Code 1 - J11: Power: Record* +17.49 dBm
(3 dB more than "Channel 99" power)

Code 2 - J11: Power: Record* +17.49 dBm
(3 dB more than "Channel 99" power)

* Add 20 dB to measured values.

TEST DATA SHEET

U.T.S.

R/T Control Unit Serial No. 004

6.2 CW Performance

"Channel 72" - J13 Frequency: 1646.25045 MHz (1646.250 MHz ± 500 Hz) Power:* +14.9 dBm (+10 dBm minimum)

"Channel 51" - J13 Frequency: 1646.18442 MHz (1646.184375 MHz ± 500 Hz) Power:* +14.9 dBm (+10 dBm minimum)

"Channel 99" - J13 Frequency: 1646.31607 MHz (1646.315625 MHz ± 500 Hz) Power:* +14.9 dBm (+10 dBm minimum)

6.3 PN Code Generation

Code 1 - J13: Power: Record* +16.6 dBm
(3 dB more than "Channel 99" power)

Code 2 - J13: Power: Record* +16.6 dBm
(3 dB more than "Channel 99" power)

* Add 20 dB to measured values.

TEST DATA SHEET

7.1 ANALOG PERFORMANCE

UTS S/N 001

FREQ. SEL "A"

CW INPUT POWER LEVEL	WB OUTPUT	NB OUTPUT
-65 DBM	-51	-27
-60	-45	-19
-50	-35	-19
-40	-25	-19
-30	-16	-19
-20 DBM	-6	-19

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FREQ. SEL "B"

CW INPUT POWER LEVEL	WB OUTPUT	NB OUTPUT
-65 DBM	-50	-25
-60 DBM	-45	-19
-50 DBM	-35	-19
-40 DBM	-25	-19
-30 DBM	-15	-19
-20 DBM	-5	-19

TEST DATA SHEET

7.1 ANALOG PERFORMANCE   UTS S/N 002

FREQ. SEL "A"

CW INPUT POWER LEVEL	WB OUTPUT	NB OUTPUT
-65 DBM	-37 dBm	-22 dBm
-60	-32 dBm	-22 dBm
-50	-22 dBm	-22 dBm
-40	-12 dBm	-22 dBm
-30	-3 dBm	-22 dBm
-20 DBM	+3 dBm	-22 dBm

ORIGINAL PAGE IS OF POOR QUALITY

FREQ. SEL "B"

CW INPUT POWER LEVEL	WB OUTPUT	NB OUTPUT
-65 DBM	-37 dBm	-22 dBm
-60 DBM	-32 dBm	-22 dBm
-50 DBM	-22 dBm	-22 dBm
-40 DBM	-12 dBm	-22 dBm
-30 DBM	-3 dBm	-22 dBm
-20 DBM	+3 dBm	-22 dBm

TEST DATA SHEET

7.1 ANALOG PERFORMANCE UTS S/N 003

FREQ. SEL "A"

CW INPUT POWER LEVEL	WB OUTPUT	NB OUTPUT
-65 DBM	No Lock On	
-60	-47 dBm	-21 dBm
-50	-37 dBm	-19 dBm
-40	-27 dBm	-19 dBm
-30	-18 dBm	-19 dBm
-20 DBM	-8 dBm	-19 dBm

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FREQ. SEL "B"

CW INPUT POWER LEVEL	WB OUTPUT	NB OUTPUT
-65 DBM	No Lock On	
-60 DBM	-47 dBm	-19 dBm
-50 DBM	-37 dBm	-19 dBm
-40 DBM	-27 dBm	-19 dBm
-30 DBM	-18 dBm	-19 dBm
-20 DBM	-8 dBm	-19 dBm

TEST DATA SHEET

7.1 ANALOG PERFORMANCE

UTS S/N 004

ORIGINAL PAGE IS OF POOR QUALITY

FREQ SEL "A"

CW INPUT POWER LEVEL	WB OUTPUT	NB OUTPUT
-65 DBM	-52 dBm	-25 dBm
-60	-47 dBm	-21 dBm
-50	-37 dBm	-21 dBm
-40	-27 dBm	-21 dBm
-30	-17 dBm	-21 dBm
-20 DBM	-7 dBm	-21 dBm

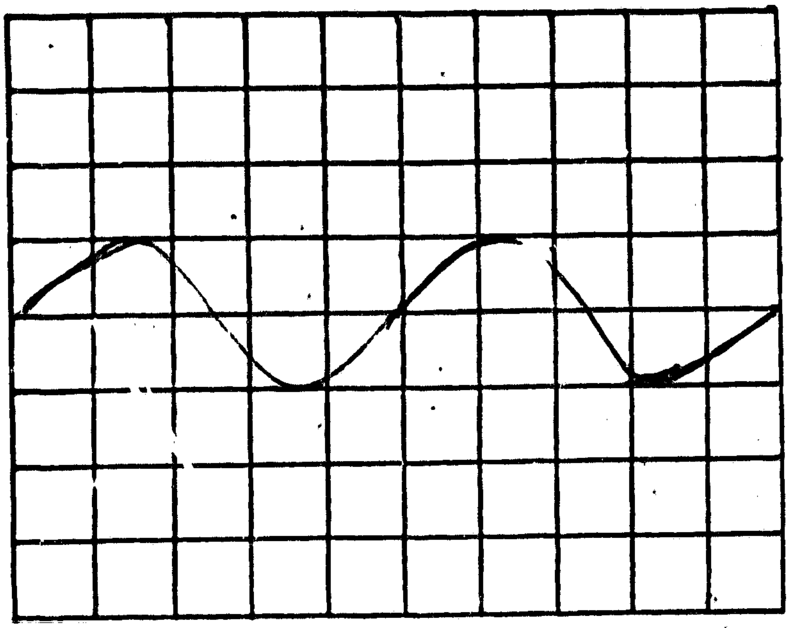
FREQ. SEL "B"

CW INPUT POWER LEVEL	WB OUTPUT	NB OUTPUT
-65 DBM	-53 dBm	-23 dBm
-60 DBM	-48 dBm	-21 dBm
-50 DBM	-38 dBm	-21 dBm
-40 DBM	-28 dBm	-21 dBm
-30 DBM	-18 dBm	-21 dBm
-20 DBM	-8 dBm	-21 dBm

TEST DATA SHEET

7.2.1 DELTA MODULATION (R/T 001TX - RT 002 RCVR)

ΔMOD 1KHZ WAVEFORM - SKETCH -



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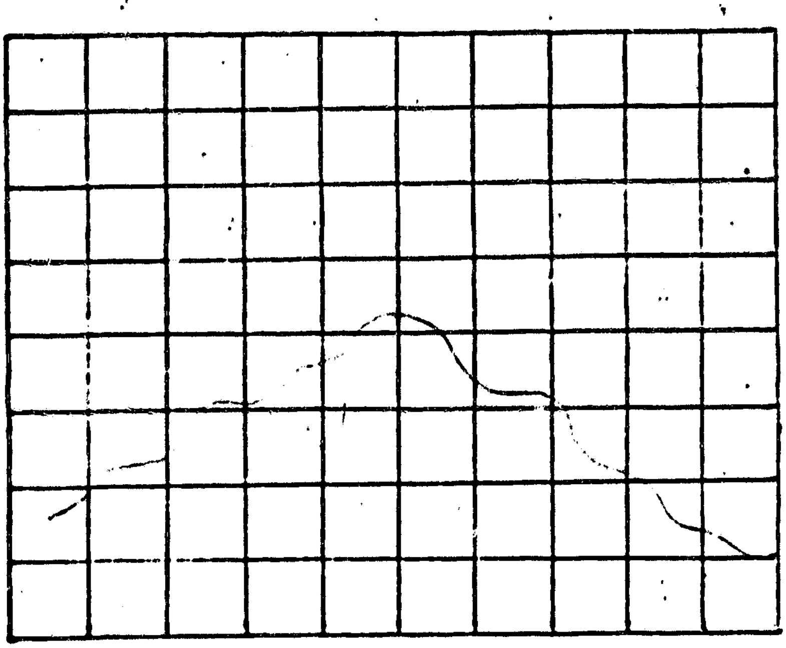
V = 100 mu/DIV

H = 200 µsec/DIV

ANALYZER BPSK WAVEFORM - SKETCH -



V = 10 dB/DIV

H = 20 kHz/DIV

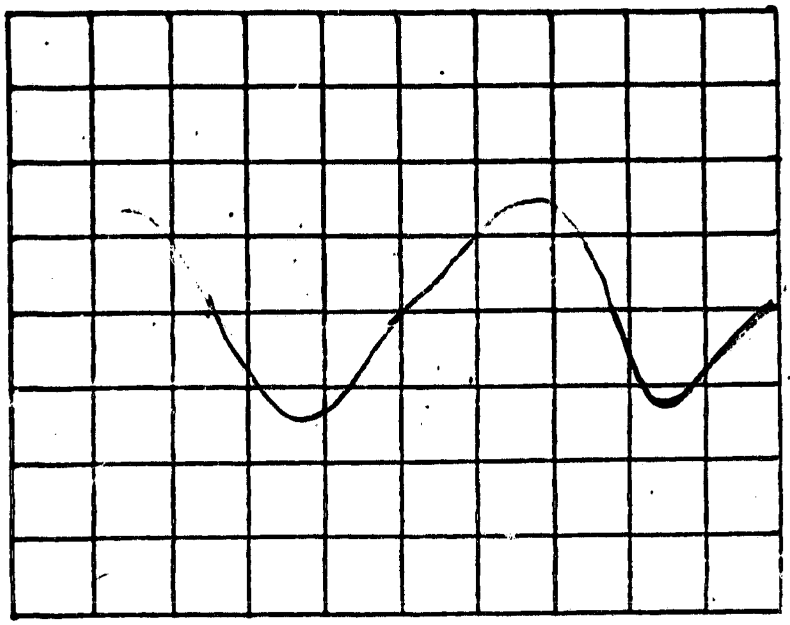
SCAN = 50 msec/DIV

f_c = 10.15 MHz

TEST DATA SHEET

7.2.1 DELTA MODULATION (R/T002 TX – RT003 RCVR)

ΔMOD 1KHZ WAVEFORM – SKETCH –



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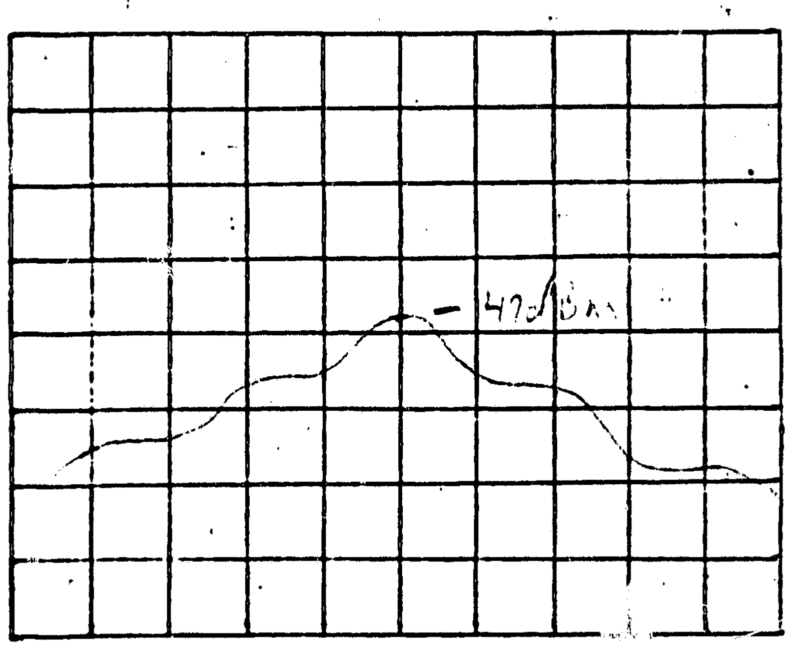
V = 100 mV/DIV
H = 200 msec/DIV

ANALYZER BPSK WAVEFORM – SKETCH –



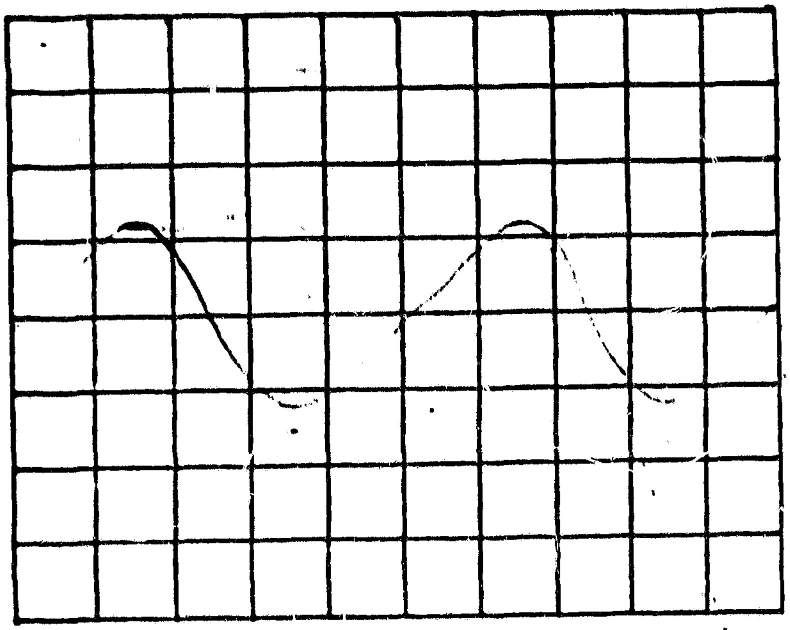
V = 10 dB/DIV
H = 20 kHz /DIV
BW = 10 kHz

f_L = 10.15 MHz

TEST DATA SHEET

7.2.1 DELTA MODULATION (R/T C03 TX - RT 004 RCVR

ΔMOD 1KHZ WAVEFORM - SKETCH -



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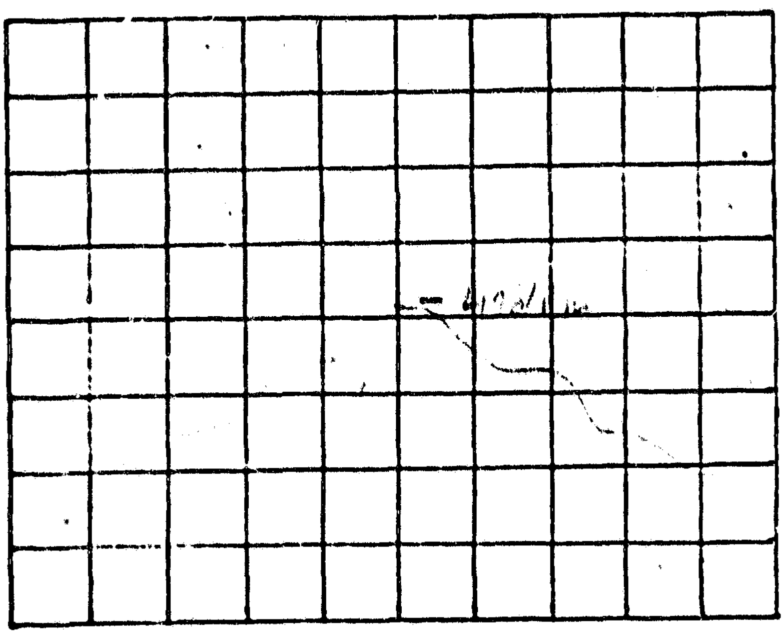
V = 100 mV/DIV

H = 200 msec/DIV

ANALYZER BPSK WAVEFORM - SKETCH -



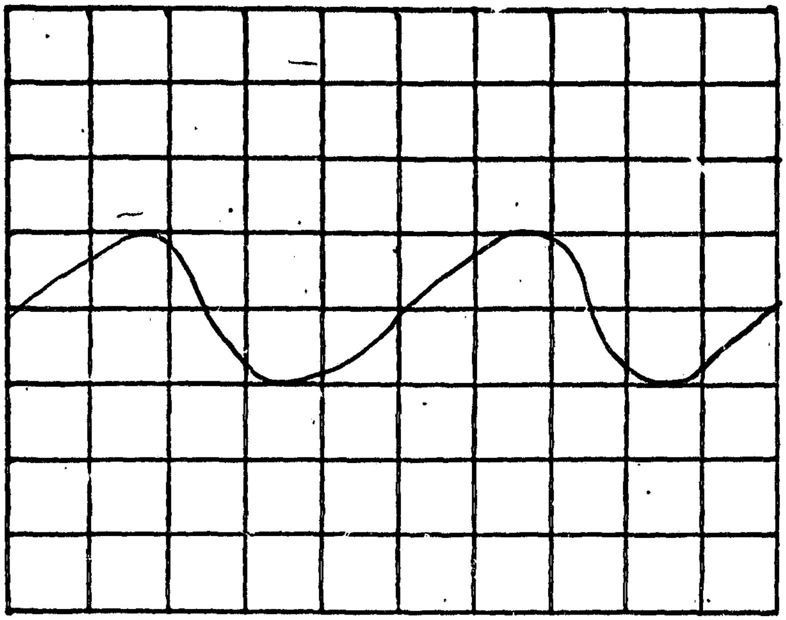
V = 10 dB/DIV

f_c = 10.15 MHz

TEST DATA SHEET

7.2.1 DELTA MODULATION (R/T 004 TX - RT 001 RCV

ΔMOD 1KHZ WAVEFORM - SKETCH -

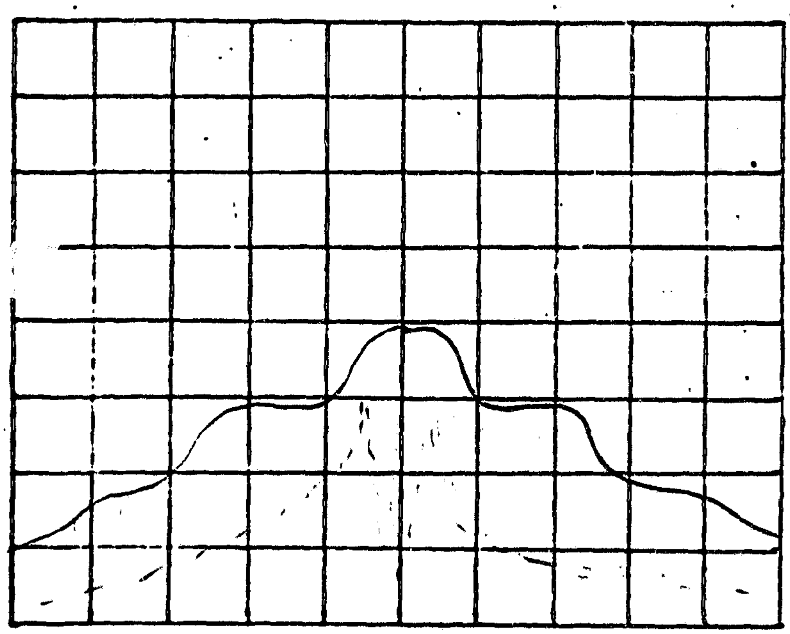


ORIGINAL PAGE IS OF POOR QUALITY

V = 100 mV/DIV

H = 200 msec/DIV

ANALYZER BPSK WAVEFORM - SKETCH -



V = 10 dB/DIV
H = 20 kHz/DIV
BW 10 kHz

TEST DATA SHEET

7.3 FREQUENCY MODULATION (R/T 001 Tx - R/T002 Rc

IKHZ WAVEFORM :- SKETCH -

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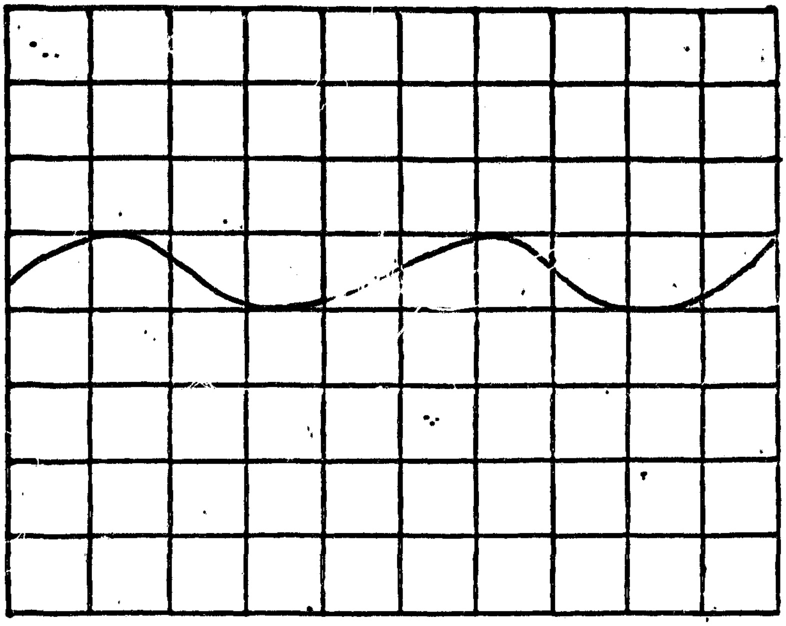
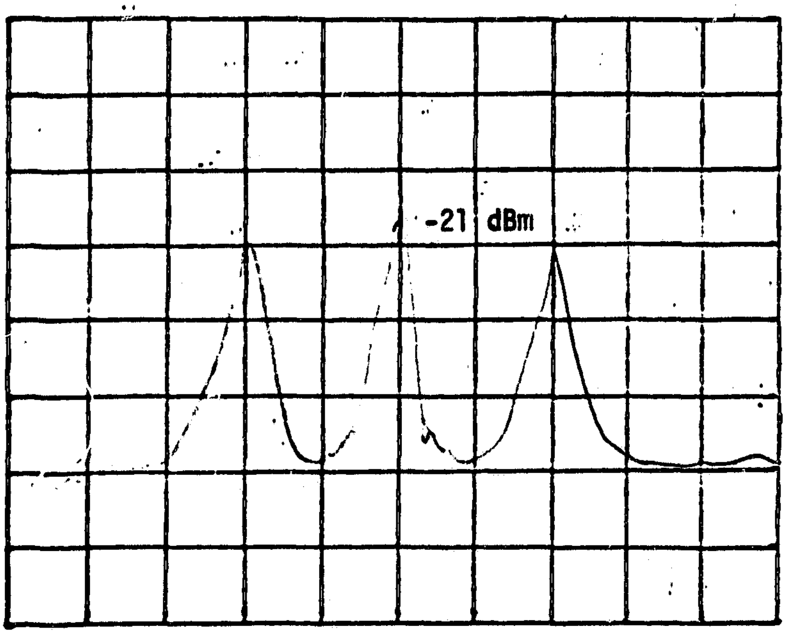


v = 50 mV/DIV
H = 200 msec/Div

ANALYZER FM WAVEFORM - SKETCH -

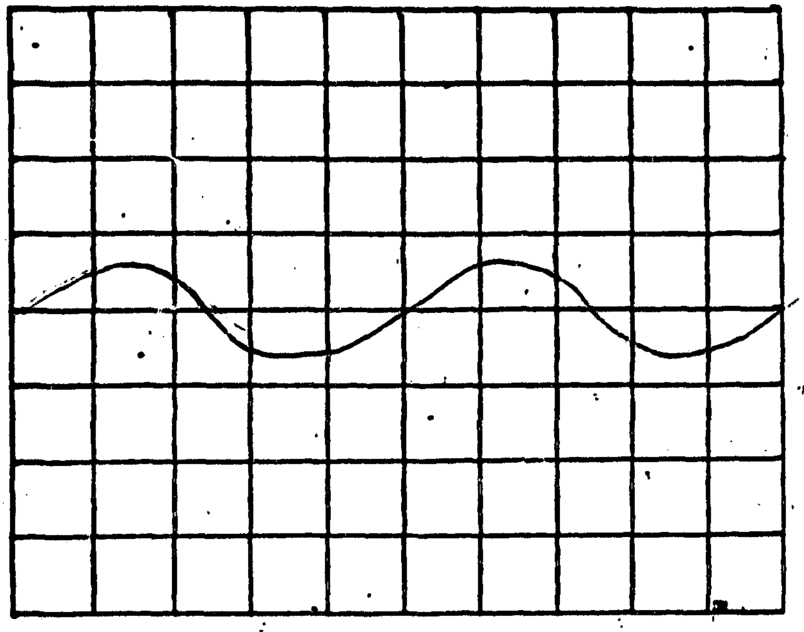


V = 10 dB/DIV
Horiz = 500 Hz/DIV
BW = 300 Hz

f_L = 10.15 MHz

7.3 FREQUENCY MODULATION (R/T 002 TX-R/T008Rc

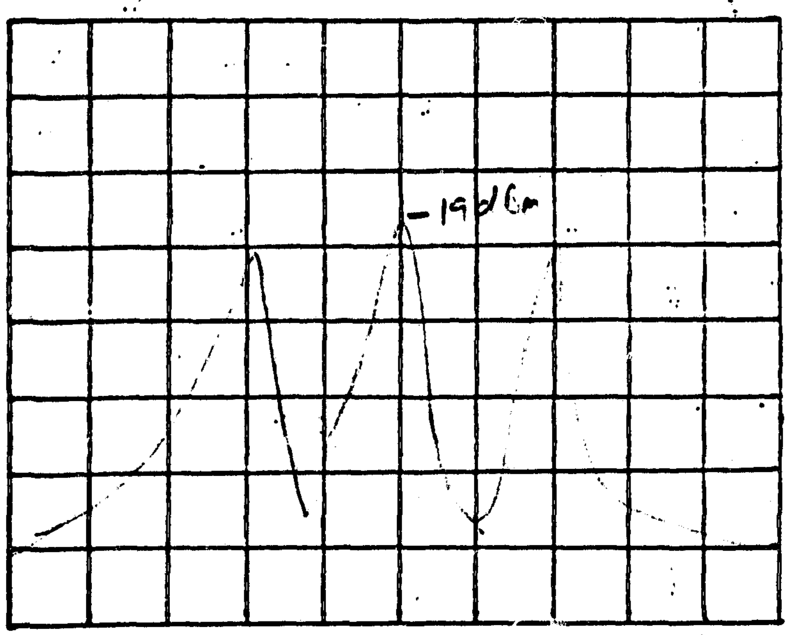
1KHZ WAVEFORM :- SKETCH -



V = 50 mV/DIV

H = 200 msec/DIV

ANALYZER FM WAVEFORM - SKETCH -



V = 10 dB/DIV

H = 500 Hz/Div

BW = 300 Hz

TEST DATA SHEET

7.3 FREQUENCY MODULATION (R/T 003 Tx - R/T 004 Rcv

1KHZ WAVEFORM :- SKETCH -

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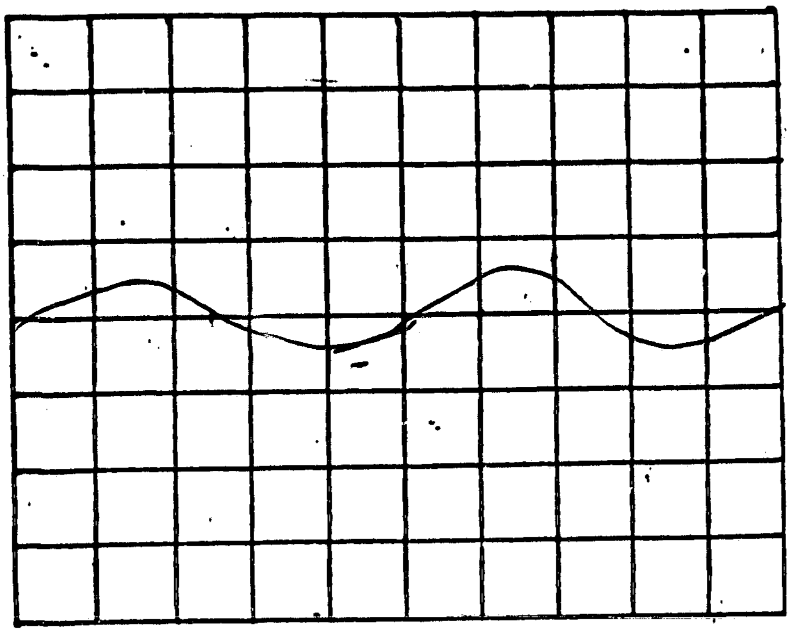
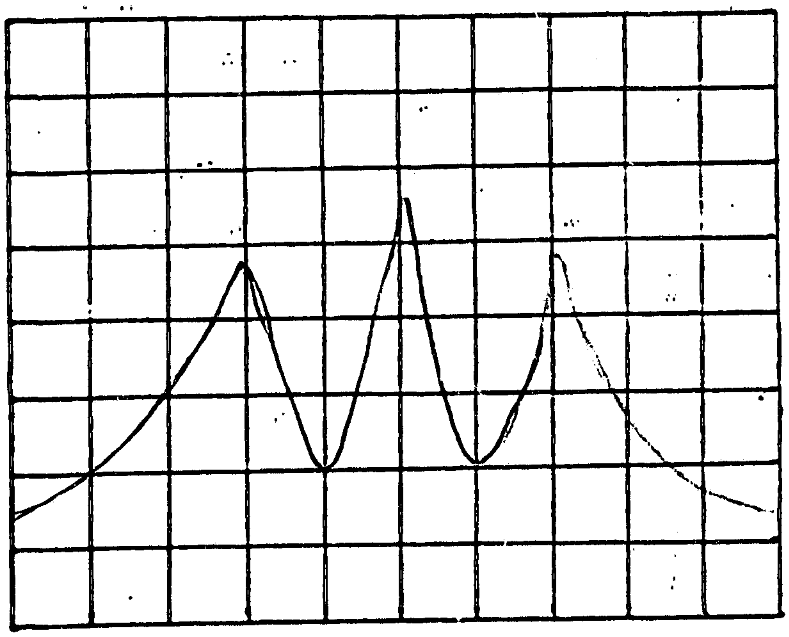


V - 50 mV/DIV

H - 200 msec/DIV

ANALYZER FM WAVEFORM - SKETCH -



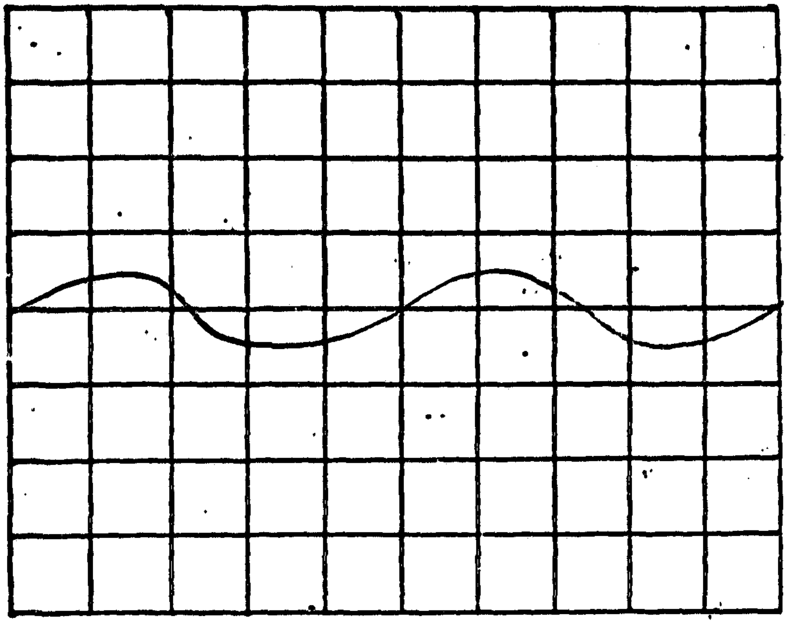
V = 10 dB/DIV
H = 500 Hz/DIV
BW = 300 Hz

TEST DATA SHEET

7.3 FREQUENCY MODULATION (R/T 004 Tx - R/T 001 Rcv)

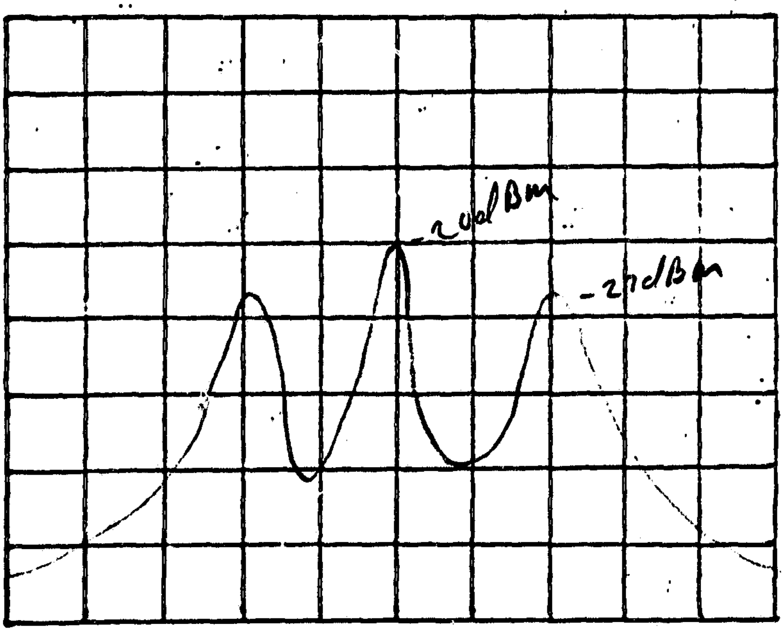
1KHZ WAVEFORM :- SKETCH -

ORIGINAL PAGE IS OF POOR QUALITY



V = 50 mV/DIV
H = 200 mSec/DIV

ANALYZER FM WAVEFORM - SKETCH -



V = 10 dB/DIV
H = 500 Hz/DIV
BW = 500 Hz

f_c = 10.15 MHz fc = 10.15 MHz

7.4 DIGITAL MODULATION

RT S/N 004 TX – RT S/N 001 RCVR

DATA RATE

CLOCK RATE

CLOCK RATE		.25 KHZ	0.5 KHZ	1 KHZ	2 KHZ	4 KHZ	8 KHZ	16 KHZ	32 KHZ
1 KHZ	FREQ. AMPL.	250 Hz ±8V	500 Hz ±8V	DC LEVEL +8V					
2 KHZ	FREQ. AMPL.			1000 Hz ±8V	DC LEVEL +8V				
4 KHZ	FREQ. AMPL.				2 kHz ±8V	DC LEVEL +8V			
8 KHZ	FREQ. AMPL.					4 kHz ±8V	DC LEVEL +8V		
16 KHZ	FREQ. AMPL.						8 kHz ±8V	DC LEVEL +8V	
32 KHZ	FREQ. AMPL.	250 Hz ±8V	500 Hz ±8V	1000 Hz ±8V	2 kHz ±8V	4 kHz ±8V	8 kHz ±8V	16 kHz ±8V	DC LEVEL +8V

7.4 DIGITAL MODULATION . RT S/N 001 TX – RT S/N 002 RCVR

DATA RATE

CLOCK RATE

		.25 KHZ	0.5 KHZ	1 KHZ	2 KHZ	4 KHZ	8 KHZ	16 KHZ	32 KHZ
1 KHZ	FREQ.	250 Hz	500 Hz	DC LEVEL					
	AMPL.	±8V	±8V						
2 KHZ	FREQ.			1 KHz	DC LEVEL				
	AMPL.			±8V	±8V				
4 KHZ	FREQ.				2 kHz	DC LEVEL			
	AMPL.				±8V	±8V			
8 KHZ	FREQ.					4 kHz	DC LEVEL		
	AMPL.					±8V	±8V		
16 KHZ	FREQ.						8 kHz	DC LEVEL	
	AMPL.						±8V	±8V	
32 KHZ	FREQ.	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	16 kHz	DC LEVEL
	AMPL.	±8V	±8V	±8V	±8V	±8V	±8V	±8V	±8V

7.4 DIGITAL MODULATION   RT S/N 002 TX - RT S/N 003 RCVR

DATA RATE

CLOCK RATE		.25 KHZ	0.5 KHZ	1 KHZ	2 KHZ	4 KHZ	8 KHZ	16 KHZ	32 KHZ
1 KHZ	FREQ. AMPL.	250 Hz ±8V	500 Hz ±8V	DC LEVEL ±8V					
2 KHZ	FREQ. AMPL.			1 kHz ±8V	DC LEVEL +8V				
4 KHZ	FREQ. AMPL.				2 kHz ±8V	DC LEVEL +8V			
8 KHZ	FREQ. AMPL.					4 kHz ±8V	DC LEVEL +8V		
16 KHZ	FREQ. AMPL.						8 kHz ±8V	DC LEVEL +8V	
32 KHZ	FREQ. AMPL.	250 Hz ±8V	500 Hz ±8V	1 kHz ±8V	2 kHz ±8V	4 kHz ±8V	8 kHz ±8V	16 kHz ±8V	DC LEVEL +8V

7.4 DIGITAL MODULATION RT S/N 003 TX - RT S/N 004 RCVR

CLOCK RATE		DATA RATE .25 KHZ	0.5 KHZ	1 KHZ	2 KHZ	4 KHZ	8 KHZ	16 KHZ	32 KHZ
1KHZ	FREQ. AMPL.	250 Hz ±7.5V	500 Hz ±7.5V	DC LEVEL +7.5V					
2KHZ	FREQ. AMPL.			1 kHz ±7.5V	DC LEVEL +7.5V				
4KHZ	FREQ. AMPL.				2 kHz ±7.5V	DC LEVEL +7.5V			
8KHZ	FREQ. AMPL.					4 kHz ±7.5V	DC LEVEL +7.5V		
16KHZ	FREQ. AMPL.						8 kHz ±7.5V	DC LEVEL +7.5V	
32KHZ	FREQ. AMPL.	250 Hz ±7.5V	500 Hz ±7.5V	1 kHz ±7.5V	2 kHz ±7.5V	4 kHz ±7.5V	8 kHz ±7.5V	16 kHz ±7.5V	DC LEVEL ±7.5V

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TEST DATA SHEET

U.T.S.

7.5 BERT Tests	Sync Lamp Extinguisher	End Test Lamp Illuminated	Error Count
TX 1/REC 2			
1 KBPS	✓	✓	0
8 KBPS	✓	✓	1
32 KBPS	✓	✓	1
TX2/REC 3			
1 KPBS	✓	✓	0
8 KBPS	✓	✓	2
32 KPBS	✓	✓	1
TX3/REC 4			
1 KBPS	✓	✓	0
8 KBPS	✓	✓	0
32 KBPS	✓	✓	0
TX4/REC 1			
1 KBPS	✓	✓	0
8 KBPS	✓	✓	0
32 KBPS	✓	✓	0

TEST DATA SHEET

U.T.S.

8.0 Duplex Operation

U.T.S. #1

WB1 : Power:	-49	dBm	-50 dBm minimum
Transmit Power:	-47	dBm	-50 dBm minimum
Transmit Frequency:	1646.25	MHz	1646.250 MHz ±500 Hz

U.T.S. #2

WB2 : Power:	-29	dBm	-50 dBm minimum
Transmit Power:	-43.5	dBm	-50 dBm minimum
Transmit Frequency:	1646.25	MHz	1646.250 MHz ±500 Hz

U.T.S. #3

WB3 : Power:	-44	dBm	-50 dBm minimum
Transmit Power:	-43.5	dBm	-50 dBm minimum
Transmit Frequency:	1646.25	MHz	1646.250 MHz ±500 Hz

U.T.S. #4

WB4 : Power:	-45	dBm	-50 dBm minimum
Transmit Power:	-46	dBm	-50 dBm minimum
Transmit Frequency:	1646.25	MHz	1646.250 MHz ±500 Hz

TEST DATA SHEET

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9.0 RFIS

9.1 Switch Matrix

Field Probe Position	Input Connector	Output Connector	Measured Power	Expected Power
OFF	J7	J6	-1.2 dBm	-2 dBm min.
ANT 1	J7	J8	-2.0	-3 dBm min.
OFF	J10	J9	-1.71	-2
ANT 2	J10	J8	-2.06	-3
OFF	J12	J11	-1.79	-2
ANT 3	J12	J8	-2.16	-3
OFF	J14	J13	-1.74	-2
ANT 4	J14	J8	-2.01	-3

9.2 Interference Source

Source "A"	Source "B"	Output Power J3	Frequency J3	Output Power J4	Frequency J4
1646.225	1646.275	-7.0 dBm	1646.215 MHz	-7.6 dBm	1646.264 MHz
1646.275	1646.225	-8.23	1646.264	-7.0	1646.215
1646.225	1646.225	-7.0	1646.215	-7.0	1646.215
1646.275	1646.275	-8.23	1646.264	-7.6	1646.264

Nominal Power: −8 dBm Minimum

Nominal Frequency: Source ±15 kHz

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9.2 Interference Source (Cont'd.)

Attenuator Level Setting	Output Power J3	Output Power J4	Expected Power
3 dB	-11.2 dBm	-11.6 dBm	-11 dBm ± 1 dB
0 dB	-8.2 dBm	-7.6 dBm	-8 dBm ± 2 dB
15 dB	-23.15	-22.6	- 23 dBm ± 2 dB
31 dB	-39.7	-39.0	- 39 dBm ± 2 dB

9.3 E.I.R.P.

Attenuator Level Setting	Source Frequency/Connector	Received Power	Expected Power
0 dB	1646.225/J3	dBm	-73 dBm minimum
10 dB			-83
15 dB			-88
20 dB			-93
0 dB	1646.275/J3		-73 dBm minimum
10 dB			-83
15 dB			-88
20 dB			-93
0 dB	1646.225/J4		-73 dBm minimum
10 dB			-83
15 dB			-88
20 dB			-93
0 dB	1646.275/J4		-73 dBm minimum
10 dB			-83
15 dB			-88
20 dB			-93

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TEST DATA SHEET

10.0 MANUAL TEST RACK

10.1 DC Source Voltage 14.25V to 15.75V +15.0 VDC

10.2 Frequency Reference

Output Power +7 dBM (+5 dBM Minimum)

Frequency 170.001 MHz (170 MHz ± 1.5 kHz)